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THE GERMAN SUPPLY PROBLEM ON THE EASTERN FRONT

(June 22 - December 6, 1942)

No theater of war is being watched as closely today as the Russo-German front. Possible increased German operations there this year constitute one of the basic questions of Allied strategy. This study attempts to help answer this question by analyzing the German campaign from June 22 to December 6, by estimating German supply requirements, by determining how these supplies were transported to the Eastern Front, and by examining the climatic conditions in order to determine the role played by the weather in timing the campaign.



March 25, 1942

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(June 22 - December 6, 1941)

Monograph No. 6

Prepared by .

Economics Division

Research and Analysis Branch

Coordinator of Information

March 25, 1942

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PHASES OF GERMAN CAMPAIGN IN RUSSIA



CONCLUSIONS

Consumption of supplies by German armed forces on the Eastern Front from June 22 to December 6, 1941, and the facilities available for their transport are examined quantitatively in this study. Nearly 200 organized divisions, representing about 5,000,000 men, were used in the initial drive; by the end of the campaign these figures had been reduced by 25 percent, and it is probable that no more than 85 divisions were left in Russia during the winter.

1. Tonnage consumed daily varied widely; but on the average it is calculated that the transport system was called upon to bring up about 575 tons per division each day, in order to support the ground operations which occurred over the length of the campaign.

2. Despite the apparent efficiency with which the Germans have adapted 10 main Russian rail lines to supply their armies, a relative inadequacy of rail transport has persisted and has imposed certain limitations on German military operations.

(a) Rail capacity to the most advanced railheads was consistently insufficient, forcing dependence on motor transport for substantial distances.

(b) At times the rail capacity was insufficient to carry supply requirements even as far as the major bases established somewhat farther to the rear. To the extent that this deficiency could not be covered by coastal and inland water transport, supplementary long-haul motor transport could be relied on where distances and tonnages involved were not too great. Otherwise the German armies

were forced to reduce the scale of their activities for periods long enough to permit accumulation of supplies for a new push. The resulting general unevenness in German activity is reflected in the average tonnages consumed, which varied from 370 tons per day per division during one of the more quiet periods to 835 tons per day in the period of the drive on Smolensk.

3. The final German assault on Moscow has been examined in detail. Despite a relatively high rate of expenditure, transport facilities appear to have been sufficient to deliver the requisite tonnage to the advance railheads. No over-all supply deficiency has been disclosed. It is possible, but not definitely established, that weather conditions may have lessened the efficiency of motor transport, and caused supply deficiencies at certain points in the German fighting line. On the whole, however, Russian resistance appears to have been the decisive factor.

4. During the final period of the German offensive it is calculated that some 160,000 freight cars, or about 10 percent of the total number available to the Axis, were diverted from use elsewhere to supply the needs of the German armies in Russia. Germany had the transport resources of nearly all Europe on which to draw, and it is probable that most of the cars required were obtained at the expense of civilians in occupied countries; but it is unlikely that the above requirements were met without some diversion of rolling stock from uses in the German war economy itself. An extension of the campaign to the east during the summer of 1942, involving longer hauls, must further deplete the transport resources available to the German war economy, unless the magnitude of German

offensive power is to fall markedly short of levels attained in 1941. Every 200 km. of German advance into Russia will require the use of some 35,000 additional cars over the figure reached at the end of 1941; or else a reduction of about 10,000 tons in the quantity of supplies that can be delivered to the front line each day.

5. Winter conditions rendered railway and truck operations difficult. Supply requirements in relation to reduced transport capacity, from December 6, 1941, to the end of March 1942, are believed to have precluded the building up of advanced supply stores on the Central and Northern **Fronts** equivalent to those available in June 1941. It seems unlikely, therefore, that major offensives will be launched in those areas at the dates calculated to represent the earliest moments permitted by weather conditions: April 24 in the center, May 9 around Leningrad. It is possible, however, that because of milder winter weather, adequate stores have been built up on the **Southern Front**; and the problem of supply, in itself, should not preclude an offensive there after April 6, when weather conditions will permit mechanized operations.

6. In conjunction with other factors affecting the German military potential, the supply position, particularly with reference to stocks at major bases, appears to indicate a significant reduction in over-all strength of the German armies in the spring of 1942 compared with the summer of 1941. This statement implies nothing as to the relative strengths, in the Spring of 1942, of the German and Russian armies. Russian strength may well have been reduced in even greater proportion than the German.

SUMMARY

1. Purpose and Scope of the Study

The German supply problem on the Eastern Front and its relationship to strategy, tactics, and the rate of advance are examined in this study. The knowledge gained through the study, it is hoped, will facilitate appraisal and understanding of possible German military operations in 1942.

More specifically, the study represents an effort to estimate the quantities of supplies and equipment of all kinds required by German forces on the Eastern Front and the transport facilities needed and available to move men and materiel to the front. Ideally, it would have been desirable to measure as well the additional transport burden imposed by the Russian campaign on the internal German transport system, and to trace fully its various ramifications. It has in fact, been necessary to confine the investigation largely to the area of combat, avoiding the elusive complexities involved in an attempt to measure with precision the effects on transport within Germany. In military language, the supply problems dealt with are those of the Theatre of Operations only, not those of the Zone of the Interior.

For the purposes of the study it has seemed both reasonable and convenient to assume that three initial supply bases were established at Königsberg, Warsaw, and Lublin. The study deals only with the transport of men and supplies after they reach these cities. No attempt has been made to measure the transport load involved in the accumulation of reserves at these points prior to the invasion of Russia, or in the continued movement of supplies as far as Königsberg, Warsaw, and Lublin from the various centers of production in Europe.

Despite this simplification, the task of measuring the German supply problem was formidable, particularly in view of the scarcity of direct information. The inadequacy of basic data and the resulting imprecision in computed results can scarcely be emphasized too strongly. To arrive at reasonably accurate conclusions about Germany's supply problem in the Russian campaign, it was necessary to secure information about the organization of the German army and air force; the service of supply; the quantities and kinds of ration and clothing allowances; the number and type of ordnance and other equipment allocated to the various army units; the standard rates of fuel consumption; the disposition of German troops; the distances moved in different kinds of combat; the supply routes; the location of principal supply bases; the distances between supply points; and so forth. Wherever possible, reliable German information on these items was utilized. The numerous gaps were filled on the basis of comparable United States figures. Where neither of these possibilities was present, estimates were made after consultation with the appropriate branches of the Army and, in some instances, civilian technical experts. Responsibility for all estimates, however, is our own.

Before presenting the findings of the study with regard to required supplies and available transport capacities it will be useful to examine briefly the organization, functions, and problems of supply, the types of transport facilities available, and the manner in which these faci-

lities may act as limiting factors on military action.

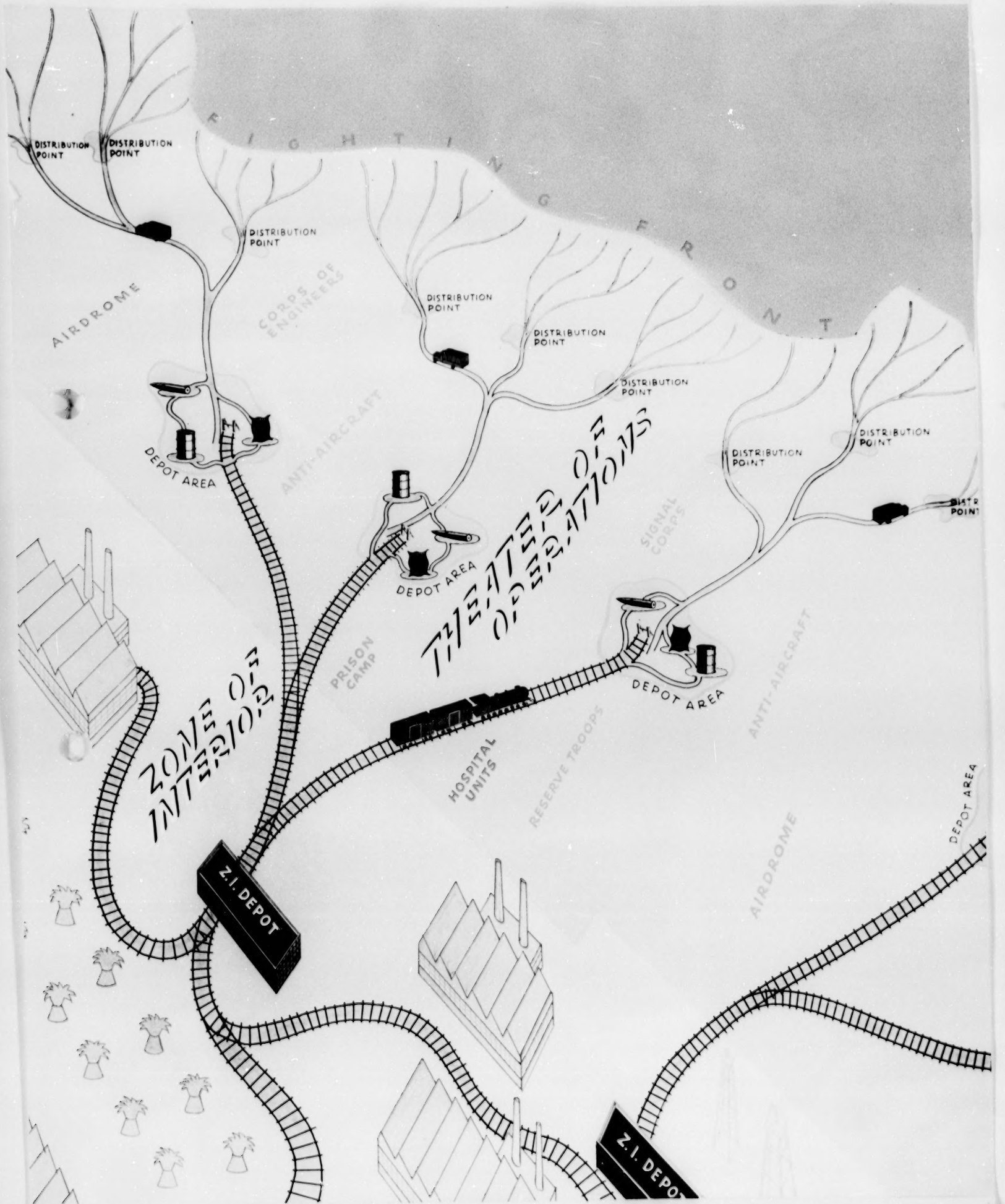
2. Organization of Supply

Although various systems of military supply differ considerably in detail, and the actual operation of any system will reveal significant divergences from its organizational blueprint, a degree of uniformity in the overland supply pattern for all armies is ensured by one cardinal fact: the inescapable necessity of maintaining a flow of supplies from the collection depots in the Zone of the Interior to the combat troops in the field.

The basic supply pattern of an army is one in which supplies move from the ZI collection depots to centers located within the TO but safely to the rear of the actual front. These may be either major bases or advance railheads, smaller and closer to the front. Reserve supplies are accumulated at both major bases and advance railheads; but it is at the latter that supplies destined for front-line use, which constitute the bulk of the total, are broken down into smaller units and dispatched by motor truck to the Distribution Point (dp). At the dp, of which there tends to be one for each combat division, supplies are further divided for distribution by truck or horse-drawn vehicle to the men in the field; and in most instances administrative responsibility passes from General Headquarters and Army to the field command.

The foregoing highly conventionalized picture is schematically illustrated in the following diagram.

SCHEME OF ARMY SUPPLY SYSTEM



It is to be noted that there are troops to be supplied all along the line from ZI to the dp-combat troops held in reserve; artillery and antiaircraft batteries; signal, reconnaissance, and supply units; and engineers. Some of these troops are under General Headquarters Command and are referred to hereafter as GHQ troops. Thus, although there are only 16,000 men in a typical German infantry division, fully equipped for front-line duty, and only 14,000 and 11,000 in motorized and panzer divisions, respectively, the total number of men in the armed ground forces works out to an average of 25,000 for each organized division. The air force, the labor force (Todt organization), prisoners, and other units or groups also require supplies.

The precise system by which the flow of supplies from the ZI to the front is maintained perhaps never corresponds exactly with the generalized description which has been given. It depends upon a number of variable factors. The location, character, and capacity of rail and motor roads, for example, and the nature of loading, unloading, and storage facilities, influence decisions concerning the location of major bases and advance railheads (which are not distinguished on the diagram). Among the former were those at Pskov, Velikie Luki, Smolensk, Kiev, Dnepropetrovsk. The latter are believed to have been pushed out, during the last stages of the advance, as far as Krasnogvardeisk, Chudovo, Mozhaisk, Kaluga, Sukhinichi, Lozovaya, and Melitopol. Other

factors necessitating modifications in the basic system of supply are the disposition of troops and supply trains; the speed of the advance; the character of the fighting; and the weather. When the troops get a long distance from a railhead, for example, it is customary to establish Transfer Points (not shown on the diagram) between the railhead and the dps. Under this arrangement, available reserve trucks under GHQ command are used to haul supplies from the railhead to the Transfer Point, where the trucks attached to the division begin to operate. Obviously, the extent and character of existing transport facilities influence many of the actual field decisions with respect to supply.

3. Character and Significance of Transport Facilities

The extent and character of transport facilities may at times also exercise a considerable influence on strategy and tactics. This will be the case, for example, where transport facilities are limited in relation to the force that could otherwise be equipped and maintained in the field. It will also be the case, as indicated below, where the limits of transport capacity affect the timing of operations by a given force.

4. Motor Vehicles

The generous utilization of motor vehicles and other wide-ranging, fast-moving equipment by the Germans has lessened-though it has, of course, not eliminated-their dependence on fixed installations like railroads.

By far the bulk of the vehicles in each division, including approximately 70 percent of the trucks, are primarily intended for combat use and for moving men and equipment along the front. The remaining trucks in each division are assigned to hauling supplies to the front. However, a certain flexibility characterizes the actual allocation of trucks to supply services. In panzer divisions, for example, an additional 15 percent of the trucks can for short periods be made available for supply services without appreciably impairing the division's immediate fighting power. Moreover, whenever necessary, trucks under GHQ command can be assigned to reinforce the supply vehicles of particular divisions.

The accompanying table shows, for the several types of divisions, the estimated load capacity of motor vehicles assigned to supply; the daily supply requirements under conditions of maximum battle intensity; and the ratio of supply vehicle carrying capacity per trip to maximum daily requirements.

	<u>Infantry</u>	<u>Motor-</u> <u>ized</u>	<u>Panzer</u>
Capacity of supply trucks per division	375	820	1,205
Maximum daily supply requirements per division (Heavy Fighting)	900	710	775
Ratio capacity per trip to maximum daily requirements	.42	1.1	1.6

The ratio for infantry divisions suggests that a day's Heavy Fighting requires about 2 trips for all supply vehicles. In view of the low average speeds at which front

line supply vehicles must operate on Russian roads, Heavy Fighting by infantry divisions can scarcely be sustained at a distance of more than 25 miles from a supply depot without special provision for supply.

German offensive tactics rely heavily upon rapid advance thrusts by motorized and panzer divisions. In this type of action, which we have termed a Major Push, 1/ the motorized and panzer divisions are sometimes, but not invariably, accompanied by infantry. When infantry divisions are used with panzer and motorized divisions in a Major Push, however, their supply requirements are far lower than they are during periods of Heavy Fighting, falling from 900 tons 2/ a day per division to about 400 tons a day which is approximately equal to the single-trip carrying capacity of a division's supply vehicles. Hence, when infantry divisions participate in a Major Push, action can continue for at least a day without necessitating return to supply depots. This permits an advance by motorized, panzer, and any accompanying infantry divisions of as much as 100 miles beyond the supply bases. When motorized and panzer divisions are operating alone, advance pushes can proceed much farther; but a continuing flow of supplies sufficient to support the fighting power of these divisions probably cannot be maintained unless supply depots are moved to within 50-75 miles of their

*Can Trucks
operate 100 mi
per day and
height cars
but 60. (see
info)*

1/ For definition of types of action see Chapter I, pps. 51-53.

2/ All tonnage figures in this report are in short (2000 lbs.) tons.

point of operations.

The ratios in the table suggest that a motorized division can advance in a Major Push for a period exceeding a day without dependence upon additional supplies. The corresponding period for a panzer division is about 1.5 days. If allowance is made for additional capacity available in the trucks assigned to motorized and panzer divisions, the possibility of initial overloading, and the further possibility of limiting requirements to fuel, ammunition, and "iron rations," it is likely that these two types of divisions could continue active fighting in a Major Push without concern for supplies for a period of 2 days. At the end of this time, however, they would be beyond ready land contact with the forces in the rear. Distances ranging from 200 to 300 miles are involved.

In the Russian campaign there are specific illustrations of such advance action with an accompanying loss of contact between supply depots and troops. Thus, about July 20 a motorized division and an armored division, operating in the neighborhood of Vyazma and some 300 miles from the bases of Vitebsk and Minsk, largely lost their effectiveness because they became dependent upon the limited amounts of fuel, ammunition, and food which could be furnished by air. Again, during the last German attack on Moscow, toward the end of November, in a thrust from the neighborhood of Tula to beyond Kashira, a panzer division and a motorized division seem to have advanced to a point so removed from their

supply bases that their effectiveness was lost.

It must be pointed out that these are exceptional cases. For the most part, the number of trucks available and the tactics employed appear to have permitted a sufficient mobility of action to execute the advance thrusts required, without loss of supply contact or effectiveness.

5. Railroads

The basic problem of military supply is to provide an average rate of delivery at least equal to the average rate of required expenditure. As has been just seen, the provision of motor vehicles in the Germany army appears to be sufficient to assure maintenance of the maximum rate of flow which may be required from the railheads to the troops, so long as the distance between the two does not become abnormally great, weather conditions are not too unfavorable, and supplies are available in sufficient quantities at the railhead.

It is the latter consideration that lends importance to the railways, especially in Russia, where the network is sparse and where, owing to the great distances and poor roads available, only limited reliance can be placed upon extensive motor hauling. If supplies cannot be laid down at the railheads every day in amounts equal to the daily rates of expenditure during periods of active combat, it is necessary either that supplementary long-distance motor haulage be available in sufficient quantities or that reserves be accumulated at nearby bases during prior periods

of comparative quiet. The necessity of accumulating such reserves was one of the reasons why the German campaign in Russia was characterized by a series of rapid advances interspersed with periods of relative inactivity. The length of these periods was chiefly determined by the relationship between estimated requirements for the next offensive and the expected rate of delivery of supplies to the nearest railhead.

Despite the important role played by motor vehicles, therefore, the core of the supply problem on the Eastern Front is the capacity of the railroads to deliver the great quantities of supplies needed at the advance railheads. In general, to accomplish this task three prime conditions must be met: the railway network must be capable of handling the requisite number of trains; sufficient quantities of rolling stock must be available; and there must be an adequate staff of personnel skilled in the operation and administration of railways. These three elements are mutually interdependent. Before their relationship to the German supply problem on the Eastern Front can be discussed in quantitative terms, however, it is necessary to ascertain the magnitude of the transport load the railways were called upon to handle.

6. Supply Requirements

Tonnage requirements of an army in the field fluctuate widely. They vary not only with the number and type of divisions in the TO but with changes in the rates of expenditure of ammunition and of certain other supplies as the scale of combat shifts. Motorized and panzer divisions require

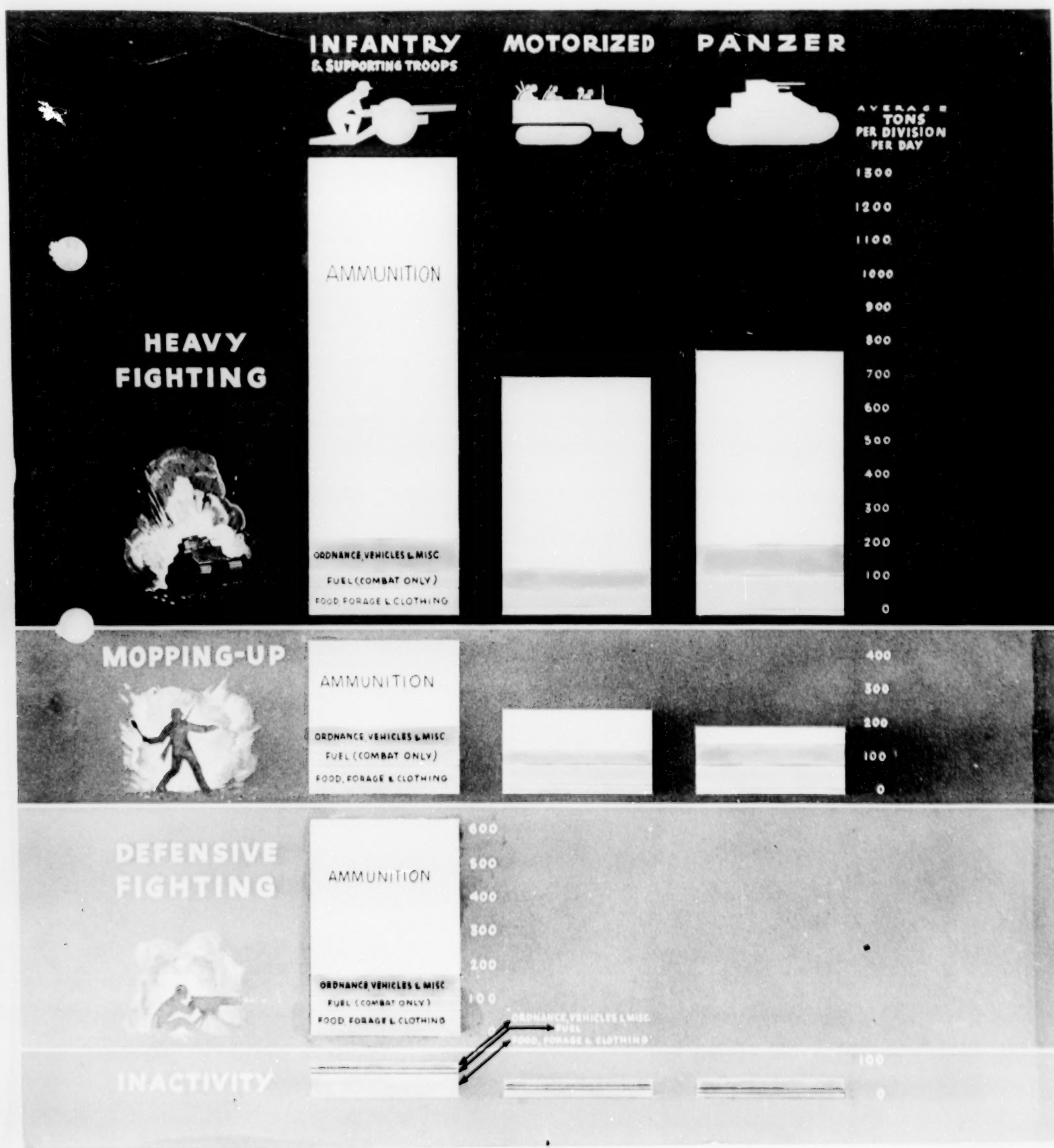
some 30 tons daily when they are inactive; in a Major Push, or during Heavy Fighting, they require about 700 tons a day. Corresponding figures for an infantry division, including a complement of some 11,000 GHQ troops, are 80 tons when they are inactive and some 1,100 tons during a day of Heavy Fighting.

In this study troop activity has been differentiated in six categories: Siege, Hopping-up, Defense, Slow Advance, Major Push, and Heavy Fighting. For each type of action, an expenditure was computed for the panzer and motorized divisions and for an infantry division, including GHQ troops. Several of these expenditure rates, by divisions, are shown in the accompanying diagram. Food and forage requirements are, of course, relatively constant. Gasoline requirements are influenced by the distances between supply depots and the division, by the forward movement in combat, and by the nature of the fighting. The diagram shows clearly, however, that supply fluctuations are primarily determined by the amount of ammunition utilized in the different types of action. Under active conditions ammunition accounts for from 50 to 80 percent of total supply requirements.

A study of the number and kind of divisions involved in the Russian campaign, and of the nature of their activities day by day, leads to the estimate that, in the entire period from June 22 through December 6, supply requirements totalled 16,650,000 tons (excluding some 500,000 tons consumed by the

GERMAN USE OF MILITARY SUPPLIES

By type of division and character of fighting

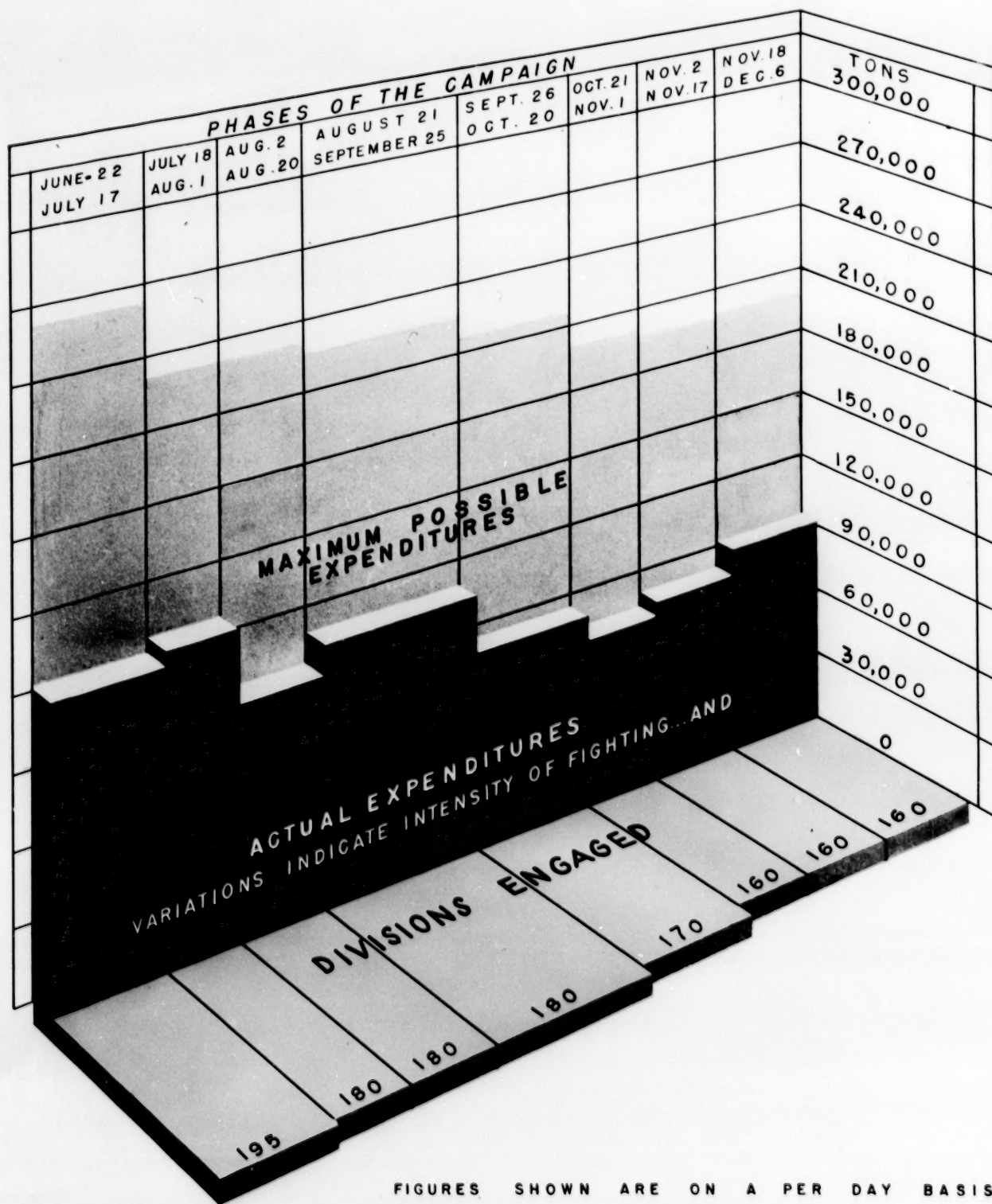


air force). For convenience in analysis, the entire June 22--December 6 span was broken into 8 periods. Taking the front as a whole, tonnages utilized by the German ground forces in Russia range from a low of 74,000 tons per day (average for each of 12 days from October 21 through November 1), to a peak average of 127,000 tons (for the 14 days ending August 1). By sectors requirements varied more widely, from 13,000 tons per day (Northern Sector, October 21-November 1) to 71,000 tons (Central Sector, July 18-August 1). These two periods and sectors also reveal the maximum range of daily requirements per division on the front--from about 370 tons per day to 835 tons per day. The extent of the variation suggests the difficulty of selecting a single figure as representing "average" expenditure per division. The arithmetic average for the ground forces works out to approximately 575 tons per division per day for the campaign as a whole.

The diagram on the following page seeks to relate actual expenditure to the theoretical maximum expenditure that would have been necessary during each period, had every division on the front been constantly engaged in Heavy Fighting, requiring maximum use of ammunition and other supplies. The upper part of the diagram shows the effect of the change in number and type of divisions from one period to another, assuming no change in the scale of fighting. The lower part of the diagram shows the actual expenditure by the same troops, after taking account of changes in the scale of

GERMAN ARMY SUPPLY EXPENDITURES

ON ALL RUSSIAN FRONTS-JUNE 22 TO DECEMBER 6, 1942



FIGURES SHOWN ARE ON A PER DAY BASIS

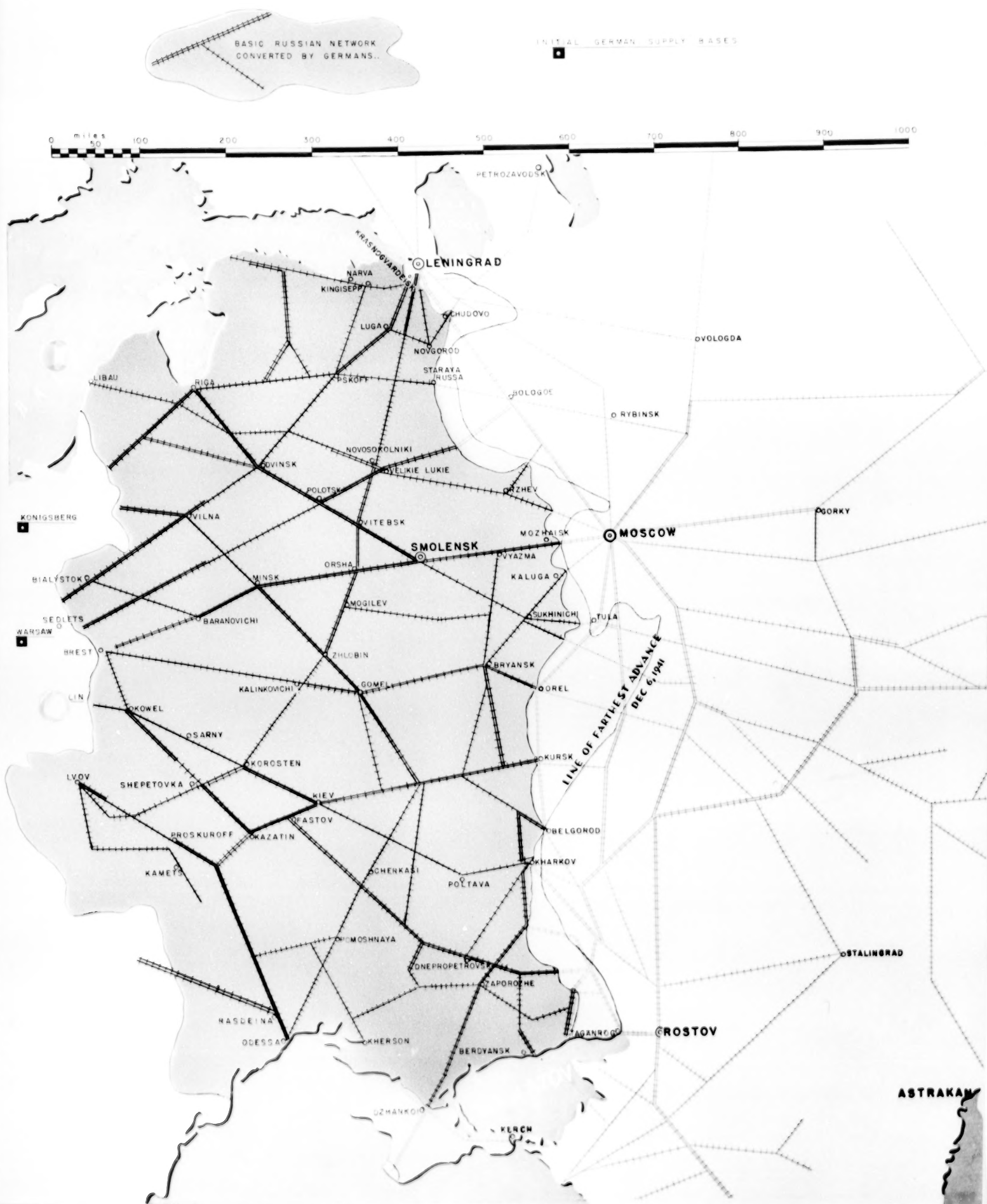
fighting. It thus indicates the effect of these changes on supply requirements. The proportions of German divisions classified as active varied considerably during the Russian campaign, averaging 59 percent for the whole period of the German offensive. Their actual utilization of supplies was only 45 percent of the theoretical maximum expenditure.

7. Capacity of Russian Railroad Lines

Study of the railway network in occupied Russia indicates that after mid-July the German army had available for its use 9 (later 10) largely independent railway lines: 3 single-track (4 after September), and 6 double-track. While some half dozen subsidiary lines were available, these are regarded as having been of such limited significance that their conversion was probably postponed. They have not, therefore, been included for statistical purposes. In this connection, it may be said that conversion of the Russian wide-gage tracks to standard gage is believed to have presented so few obstacles that the delay involved in conversion has been disregarded, except to the extent of assuming that railroad service into Russia did not begin until after the middle of July.

The problem of estimating the number of trains that the Germans could dispatch per day over the captured lines defies precision. So important are the physical individualities of railway lines and the effects of operational efficiency that the maximum traffic density over a particular length of

RAILROADS ON THE EASTERN FRONT



track can hardly be determined except empirically. It is thus extremely difficult to select meaningful averages concerning the number of trains the Germans may have been able to operate on captured Russian railways. According to railway experts, the operation of 10 trains a day in each direction is a probable maximum over single-track lines, not worked over with a particular view to increasing the traffic density. Densities as high as 40 to 50 trains a day in each direction have been achieved on certain lines with long and frequent sidings and favorable grades, where motive power and operating personnel of requisite quality and skill have been available. For short periods much higher densities, up to 85 trains a day in each direction, have been recorded for single-track lines, but these are of a most exceptional character.

Although some observers incline to the view that the Russian lines in German-occupied territory have in the last decade been adapted to heavy use, it is doubtful whether the many fundamental recommendations made by Mr. Ralph Budd in 1930 were effectively carried out on all Russian lines. Many inadequacies of roadbed and grading must have remained. It is also unlikely that the track, bridges, cuts, fills, and signal systems were left in perfect condition for the Germans. The degree of damage that was effected is unknown, but it must have been sufficient to affect German operations seriously for the first days or weeks of occupation; where refilling was necessary, moreover, trains would have to be run over the stretch at subnormal speeds for as long as 6 months, until the fill was consolidated. And near the front line operations are likely to have been impeded at all times by artillery or air bombardment, and

guerilla tactics. Signal systems are particularly vulnerable to such action, which would have the effect, particularly, of impeding night operations in areas where blackout conditions had to be observed. The net consequences of these influences must, of course, be entirely a matter of judgment; in our opinion, they would prevent the Germans from operating more than 10 trains a day, on single-track lines, over the stretches within 100 or 200 kilometers of the front.

As the front line advanced, repairs and improvements were undoubtedly made on the lines well to the rear and, as there was also less danger of air attack, operations were undoubtedly stepped up. Their upper limit, however, is difficult to fix. Almost certainly it was as high as 20 trains a day on single-track lines^{1/} and it may have been still higher. Taking 20 trains a day as the top, and starting from the base of 10 trains a day already mentioned, we have adopted 15 trains a day as the average attainment over those portions of the railway lines extending from Germany to the major bases in Russia. This figure may well be too low.

Maximum achievable traffic densities over double-track lines are ordinarily said to be two or three times those for single tracks of comparable quality. In the present study, the factor of 3 has been used, yielding figures of 30 and 45 trains a day over those portions of double-track line lying in front of, and behind, the major bases, respectively. These estimates may be too high and, if so, they may offset the possible error of underestimation in the figures for the number of trains moving over the single-track roads.

^{1/} This is the figure used in the U. S. Staff Officers' Field Manual, FM 101-10.

The 9 (later 10) routes available to the German army are thus thought to have been capable of carrying 210 trains each day (later 220) to the advance railheads, near the front line, during the first phase of each offensive, and 105 additional trains each day (later 110) to the major bases located in territory which had been longer held. Allowing for about 55 troop trains each day, and assuming that each freight train consisted of 30 cars of 16 tons capacity each, the total amount of supplies that could be carried to advance railheads would be between 74,000 and 79,000 tons a day, while 124,000 to 132,000 tons a day could be carried to the major bases. Service freight (coal, maintenance items, etc.) is assumed to absorb about 20 percent of these capacities, so that the amounts of military supplies that could be hauled each day were nearer 60,000 and 100,000 tons, respectively. The smaller transport capacity available to the advance railheads is partly counterbalanced by the fact that the quantity of supplies currently required at these points is less than the quantity required at the major bases.

Table 13, page 122 shows the tonnages estimated as having been utilized daily at the major bases and advance railheads, compared with estimated rail capacities, for each of the eight major periods into which the campaign falls. It shows, in two periods, that the estimated tonnage requirements exceeded the rail capacities for delivery to major bases; and that for delivery to advance railheads, this was the case in every period.

Rigidly interpreted, this represents, of course, an impossible situation. Actually, there are several possible explanations for the discrepancy. One is that the estimates of rail capacity, tonnage

utilization, or both, may be in error. The possible sources of inaccuracy are too numerous to list; but it may be worth mentioning specifically that significant numbers of trains may have been dispatched over other routes than the 9 or 10 included for statistical purposes.

A second possible explanation is that, to some extent, the Germans may have been able to use coastwise shipping in the Baltic and Black Seas, as well as rivers and canals inland, to carry certain supplies. A third is that motor transport was used to supplement the rail hauls. It will be observed, however, that the most consistent and the largest deficits occur in the delivery of supplies to the advance railheads, where train operation is believed to be relatively inefficient. But because the distances involved are not great, however, the number of motor vehicles that would have been required to remedy the deficiency was not in excess of those believed to be available.

The distances from the ZI to the major bases were, however, much greater. Had it been necessary continuously to run supplementary motor haul services over this whole distance the problem would have been serious. Deficits of this type are indicated in periods II and IV; and they may have involved emergency hauling on a very considerable scale. It is estimated, for example, that 1,200 thirty-ton trailers, or their equivalent, would have been required to remedy the 12,000 - ton daily deficit in Period IV.

A special interest attaches to supply calculations with respect to the final assault on Moscow, since a supply deficiency has been advanced, on occasion, as a major cause for the failure of that

assault. Table 13, mentioned above, indicates that supply facilities were adequate in Period VIII to bring the required tonnage to the major bases; while the deficit of 25 percent, for haulage to the advance railheads, is not extreme when compared to the deficiencies of Periods III and IV. Assuming that no sharp decrease had occurred in the quantity or quality of supply trucks available, transport facilities appear sufficient to handle the load indicated by the type and intensity of fighting which occurred. Our data do not indicate a general supply shortage.

There are, however, other possibilities, which must by their nature be regarded as highly speculative. In the first place, the final assault on Moscow was accompanied by fairly severe snowstorms. It is possible that these would have affected rail transport and thus lowered the tonnages which could be delivered to the advance railheads. It is even more likely that it reduced the carrying capacity, for given time periods, of the pool of supply trucks available. If there was, then, a supply problem for the Germans before Moscow, it probably stemmed from the vulnerability of the motor-transport system to weather conditions.

This situation might have had a special importance in view of the tactics employed by the Germans on this occasion. Mechanized arms of encirclement were thrown to the north and south of the city, towards Dmitrov and Skopin (see map before page 1). These arms were forced to operate some 150 miles from their initial advanced railheads. In view of the speed of the action, converting the gage of intervening rail lines was out of the question.

Truck transport was required; and the distances involved, coupled with the difficulties imposed by the weather, may have prevented the encircling arms from maintaining their momentum. In this limited sense a problem of supply may well have contributed to the German defeat at Moscow, although the strength of Russian resistance must be held primarily responsible. Resistance alone was capable of forcing a high rate of consumption on the German armies and exploiting the possibilities of adverse weather and tenuous lines of supply.

The over-all sufficiency of the rail and transport system to meet the demands upon it, as indicated in Table 13, must not be taken as evidence that the German supply problem imposed no limitations on the course of the battle. Its most important consequence can be observed in the relatively low level of activity and of supply expenditure from the end of July to about August 20, and again, from September 25 to the middle of November. Such intervals of relative quiescence, which may be traced even more clearly on each of the individual fronts, were necessitated by the need to accumulate reserves in preparation for the major advances. The supply system was incapable of bringing forward continuously the tonnage which was expended in those actions. A clear if irregular rhythm of military action may be traced, in consequence.

In addition, it appears likely that the relation between supply tonnages brought forward and consumption at the front left the German armies with relatively small reserve stores with which to face the winter campaign, or to prepare for a spring offensive.

8. Rolling Stock Requirements

The capacity of the railway network acquired by the Germans

in Russia is not the only factor potentially limiting their offensive power. There are also the factors of rolling stock and operating personnel. Even if it could be contended that the rail capacity available to the Germans was significantly greater than indicated above, it would not follow that larger tonnages were, in fact, hauled, since the necessary rolling stock and operating personnel might not have been readily spared from uses at home.^{1/}

Three factors determine rolling-stock requirements: tonnage hauled, which has already been estimated, the length of haul, and the average distance moved by a car in a day.

With respect to the last of these factors, there is a noteworthy convergence of evidence on the figure of 60 miles a day. This was the average achieved by the AEF in the last war; it represents the top of the range of experience of the Southern Railway (although American experience generally ranges between about 20 and 125 miles a day); it is approximately the average car movement for Russia cited in the report of Mr. Ralph Budd; and it is the average recorded in Germany in 1938.

Car movements of 60 miles per day may seem unreasonably low to the layman unaware of the fact that the speeds of heavily loaded freight trains are much lower than those of passenger trains, and un-

^{1/} The present section is concerned only with rolling stock requirements. The situation with respect to operating personnel is believed to be closely analogous to that with respect to rolling stock, and hence no special investigation of it has been attempted. It may be noted, however, that the difficulty of train operation in Russia may have involved requirements for skilled personnel out of proportion to the number of trains run, and so have constituted a particular problem for the Germans.

mindful of the great amount of time lost in loading, unloading, re-fueling, accelerating, decelerating, and so on; but the unanimity of opinion among men familiar with actual railway operations is convincing. And while in some respects conditions on the Eastern Front may be easier than commercial conditions, in other respects delays are likely to be worse. Two railway experts were inclined to believe that German experience might run as low as 40 miles a day. The AEF figure of 60 miles has, however, been adopted.

On the basis of this assumption, the estimates already made with respect to tonnage hauled, and the estimated average length of haul shown in the table, and allowing an addition of 30 percent for rolling stock tied up in repair shops, destroyed, and used for mobile storage, German car requirements in Russia are estimated as follows:

	Period I	Period II	Period III	Period IV	Period V	Period VI	Period VII	Period VIII
	June 22- July 17	July 18- Aug. 1	Aug. 2- Aug. 20	Aug. 21- Sept. 25	Sept. 26- Oct. 20	Oct. 21- Nov. 1	Nov. 2- Nov. 17	Nov. 18 Dec. 6
Average round- trip haul (Km.)	750	750	900	1,200	1,500	1,650	1,800	1,800
Thou- sands of cars	<u>1/</u>	75 <u>2/</u>	85	120 <u>2/</u>	125	125	145	160

1/ It is assumed that no Russian rail lines were available in this period.

2/ Figures calculated on the basis of estimated rail capacity, which was less than actual requirements in these periods. On the basis of tonnage requirements the respective figures would be as follows (in thousands of cars): 90(II) and 125(IV).

There was an adequate over-all supply of freight cars to meet these estimated requirements. Before the invasion of Poland the Greater

Reich had about 600,000 freight cars, and since that time has acquired by conquest effective control over a car stock that approximates 2,000,000. Not all of these, however, are of the same capacity or quality as those of the Reich; in terms of "German car equivalent" the figure is likely to be nearer 1,500,000.

The basic question is whether the diversion to military use in Russia of some 160,000 cars, or about 10 percent of the total supply, would interfere with economic activity in Europe. As soon as the point is reached at which increased diversion of cars will interfere measurably with the military potential it is clear that the High Command is confronted by a dilemma whenever a given strategy involves an increased use of freight cars.

No attempt has been made in the present study to measure where this point lies or to determine the extent of interference. In order to do so, we should have to know whether, at the beginning of the Russian campaign, there was any slack that could be taken up, and if so, how much. Little reliable evidence is available on this point. Nevertheless, it is being assumed that there was some slack. There was available the obvious possibility of cutting transport services for the civilian populations in occupied countries, whose needs can be almost wholly neglected without injury to the German war effort. Before the war France, Belgium, and Holland alone had some 600,000 freight cars, not all of which, probably, had been confiscated before June 1941. There was also the possibility of curtailing passenger services throughout Europe, thus releasing locomotives and cutting down on dead-head freight. It is known that, to some extent, this latter possi-

bility has been exploited, permitting the conversion of a substantial portion of the 200,000 Axis-controlled passenger cars for freight service. Resort to such measures is evidence of strain, but also of its remedy. On the other hand, the reported efforts to reduce further the loading and unloading time of freight cars, and otherwise to bring about a more intensive utilization of equipment, are less likely to have succeeded. Already, by 1939, such measures had resulted in more efficient use of cars, and it is probable that the principal opportunities for improvement had been fully exploited.

On the whole, it is difficult to believe that a diversion of about 10 percent of the available rolling stock could take place without beginning to impinge on the German military potential, especially as large numbers of cars in Europe itself had to be utilized for the Russian campaign. But the interference with German war production may not become great unless, and until, the car requirements begin substantially to exceed 200,000. As Table 17 (page 139, Chapter III) shows, rolling stock requirements would increase by about 35,000 cars for every additional 200 km. that the Germans advance into Russia, provided Russian resistance should make necessary offensive operations as costly in supplies as the final drive on Moscow. The alternative, as also indicated in the table, would be to conduct a less powerful offensive, in order to hold car requirements down to the figure reached in the latter part of 1941. This would mean a reduction of about 10,000 tons in the daily delivery rate for every 200 km. of further German advance. The feasibility of this alternative would depend on the strength of Russian resistance.

9. The Problem of Supply in Winter.

It remains to consider briefly the problem of maintaining the flow of supplies to the German armies under the conditions prevailing during the Russian winter. In winter, train operation becomes more difficult in proportion to the amount of snow and the degree of cold. Owing to resultant delays, reduced train speeds, and reduced net loads per train, a larger amount of rolling stock is required to maintain a given rate of delivery. No attempt has been made to estimate the average daily movement of a freight car under winter conditions, but it is evident that it must be less than the figure of 60 miles a day employed above. Similarly, the number of trains operated per day must be less than during the summer and fall of 1941.

In consequence, fewer supplies could have been delivered to the German armies from early December to the middle of March than during a comparable period of the 1941 campaign. And while a reduction in the estimated number of divisions to around 85, together with their comparative inactivity, might have reduced the rates of expenditure for the front as a whole to approximately 25,000 tons a day, it is probable that exceptional losses of equipment and supplies, owing to the weather and Russian pressure, and the need to provide shelter and warmth for the troops, had the effect of increasing this figure. In the light of the reduced rate of rail deliveries, and the obstacles to use of motor transport, it is doubtful that the German forces in the Northern and Central Sectors have been able to accumulate supplies much in excess of those used or lost during the winter. Conditions in the Southern Sector may, however, have been more favorable.

The conclusion is almost inescapable that the Germans are much weaker in the spring of 1942 than they were in June 1941. The effectiveness of the initial German advance resulted to a very large extent from extensive preparation and from the surprise character of the attack. The German army in June 1941 was presumably in top condition as regards manpower, morale, and equipment. Supplies had been marshalled in large quantities at the most convenient bases. In short, nothing was lacking in the way of offensive power.

The situation this spring will be vastly different. Casualties during the 1941 phase of the campaign were severe and probably affected the best troops in disproportionate measure. Subsequent losses, due both to harrassment by the Russian armies and the ravages of winter, cannot have been negligible, and many of the soldiers not on the casualty list must be in relatively poor mental and physical condition. The situation with respect to equipment is similar. Losses have been heavy, and the difficulty of caring properly for the equipment still on hand must have affected its efficiency. Diversion of manpower from industrial employment into military service has adversely affected production, and it is possible that the diversion of railway cars to military uses in Russia was sufficiently great, in conjunction with other economic deficiencies, to have a similar effect. There is reason to believe, therefore, that Germany has been unable to produce full replacements for the equipment and reserve supplies expended during the Russian campaign, and hence does not have at present the same offensive strength that she had in June 1941. Since this study has been limited to the German side of the campaign and no exam-

ination of the Russian position has been made, however, it is impossible to estimate the relative strength of the German Army of April 1942 as compared to June 1941. Nevertheless, this study strongly suggests that the Germans will not be adequately prepared to launch operations on the scale of those of June 1941 all along the Russian front at the earliest dates permitted by the weather: about April 6 in the south, April 24 in the center, and May 9 around Leningrad, as shown on the map which follows. They may, however, have succeeded in completing better preparations in the south, where the winter is less severe than in the Central and Northern Sectors. It is therefore possible that a large-scale offensive in the direction of the Caucasus may be launched at a comparatively early date. But if such an offensive does take place, its success may be compromised by the inadequate preparedness of the armies on the Central and Northern Sectors. For, should Russian strength be comparable to the most effective efforts in the past campaign, the German High Command would be unable either to gain or to retain the initiative on all fronts.

10. Content of the Supporting Chapters

The supporting chapters constitute four basic studies. The first is an analytical account of the German campaign in Russia from June 22 to December 6. This analysis serves as a frame of reference for a statistical breakdown of the campaign in terms of the number and type of divisions engaged, as well as of the duration and intensity of the military activity of those divisions.

Chapter II provides the actual estimates of German supply requirements. Data on daily requirements of ammunition, food and

RUSSIAN WEATHER CONDITIONS

Dates on which mechanized operations become feasible



other major supply categories were compiled for infantry, panzer and motorized divisions. The effect of various kinds of fighting on these supply categories was taken into account. The daily-requirements data were applied to division-day activity figures developed in Chapter I. A self-contained estimate of supply requirements of the air force is also included in Chapter II.

In Chapter III the primary task was to determine how the supplies required by the German armies were transported to the front. A detailed examination was made of motor and railroad transport facilities and of their capacity. The purpose was to appraise the adequacy of the facilities available, and to suggest how the relationship between the available transport capacity and the expenditure of supplies may have acted as a limiting factor on strategy and tactics.

Finally in Chapter IV the climatic conditions on the Russian front were examined in order to establish the role played by the weather in determining the timing of the campaign. It contains information on temperature, precipitation, and drainage conditions which, together with data on the supply situation, may serve to indicate when and where the German armies will strike this spring.

CHAPTER I. THE GERMAN CAMPAIGN IN RUSSIA

(June 22 - December 6, 1941)

A. Purpose and Scope of the Chapter

The purpose of this chapter is to provide the basis for a statistical study of German supply and transport requirements on the Eastern Front through an analysis of the military campaign. In its duration, extent and complexity, the campaign presents an intricate picture. During a period of 167 days, vast armies fought over and occupied an area of 400,000-odd square miles in a series of greatly diversified tactical movements. In spite of the confusion, however, it is possible to discern the major outlines of the campaign, which, in turn, is of help in the detailed analysis.

Specifically, after an initial generalized drive across the Russian frontier, the Germans established three separate commands to direct what have been called the Northern, Central, and Southern Fronts. On each of these fronts activity was intermittent. This fact provided another convenient and realistic classification in terms of periods of time. Since German pressure was not distributed uniformly over the three theatres of operations, the periods were chosen in most cases because of the dominating importance of operations in one or two fronts during that time. Eight such periods have been distinguished.

Thus, the whole German campaign to December 6 has been subdivided in spatial terms into the Northern, Central, and Southern Fronts, and in terms of time into eight periods. To deal with

the campaign simultaneously in terms both of the three fronts and of the time periods would involve a great deal of overlapping. Therefore, the campaign will be presented in two ways. First it will be ~~studied~~ analytically, to indicate the nature and location of the fighting and the reasons for the various pushes. In this section the campaign will be dealt with ~~mainly~~ on the basis of the three fronts. Secondly a table will be presented to show both for the fronts and for time periods the size of German forces engaged, together with the intensity and duration of fighting. The analytical section and the statistical section do not derive one from the other; rather both derive from the raw material of the events themselves.

B. Analytical Study of the German Campaign

The nature of German operations in Russia from June 22 to December 6 leads to the belief that a major shift of Nazi strategy took place during the campaign. This belief is strengthened by inferences drawn from German statements on military movements and appraisals of objectives. The original strategic aim was the destruction of Russian military resistance; later operations were directed toward seizing and holding important territory and cities. Thus in the first phase such an important center as Kiev was by-passed in an effort to trap and destroy the Russian armies in the Ukraine, and German statements on this offensive were all in terms of smashing Russian armed resistance. By contrast, the second phase of operations was characterized by such efforts as the attempt to hold Rostov and to take Leningrad, while German statements dwelt on the strategic importance of the

cities themselves.

The contrasting aims in the two phases are reflected in the character of the offensives. During the first phase, which runs roughly from the outbreak of the war to October 20, four major offensives can be distinguished: (1) The initial push across the frontier into Russian-occupied Poland, the Baltic States, and White Russia (June 22 - July 2 or 3) and the cracking of the so-called "Stalin Line" (July 9-16 or 17); (2) the drive into the Western Ukraine (August 2-September 25); (3) the drive on Leningrad (August 12-September 25); and (4) the Vyazma-Bryansk-Rzhev push which coincided with a drive into the Donets Basin (October 2 - October 20).

When the last of these offensives failed to end Russian resistance, the German plan of campaign was then focussed on an effort to capture Moscow and Leningrad and to break through to the Caucasus. This second phase of German operations began with the forcing of the Perekop Isthmus about October 30, followed by a drive into the Crimea. After the capture of Kerch on November 17, the Germans launched a new offensive in the Donets Basin, probably aimed at effecting a junction with forces pushing across the Kerch Straits towards Krasnodar. This operation was designed to sieze the Caucasus region. The timing coincided with a major offensive on the Central Front, which had as its objective the encirclement and capture of Moscow.

With these two phases in mind, the campaign can best be analyzed in terms of its fronts: Northern, Central, and Southern. However, the regrouping of German armies under the

three commands to which these fronts refer took place only on July 17. Up to that time there was a generalized push across the frontiers. Therefore this push will be taken as a separate unit and the campaign will be discussed in terms of the three fronts only after July 17.

One further point should be noted before outlining the actual development of German military operations against Russia. With the exception of Finland, the role played by Germany's allies in the operations against Russia was insignificant. While the Germans took great pains to emphasize the participation of Rumanians, Italians, and Hungarians in the Ukrainian offensive, the entire burden of the campaign to destroy the Russian armies in this region fell on the German army. The Finns, however, took part in the major German operation in the north designed to crush Russian resistance in the Leningrad area.

1. The Frontier Push (June 22 - July 17). This period can be broken into two main phases of forward advance separated by a lull of about a week. The first phase (June 22 - July 2 or 3) was one of heavy mechanized thrusts against the Russian frontier. The lull referred to above applies solely to the use of mechanized forces by the Germans. The second phase of the German forward advance began about July 9 or 10 and lasted until July 16 or 17. The operations during this period have been referred to as the attack on the "Stalin Line."

While the German attack on Russia began with a number of drives distributed between Northern Finland and Rumania, the main thrust of the German drive was based on East Prussia and the

northern and central portions of German-occupied Poland. These drives were aimed at over-running the Baltic States and inflicting a major defeat on the Russian armies in Russian-occupied Poland and in White Russia.

The drive through Lithuania, Latvia, and Estonia made rapid headway, focusing ultimately on the region north of Lake Peipus, in the vicinity of Narva, with the aim of effecting a junction with German forces pushing northward, east of Lake Peipus. The only effective Russian resistance offered to this drive was in the vicinity of Kaunas. In a period of 16 days from the outbreak of hostilities, the Germans drove about 350 miles, or an average of slightly over 20 miles per day. Russian troops pinched off by the Germans in Western Estonia were finally **driven out of** Tallinn and Baltic Port about September 5. Other pockets of resistance in this area were the islands of Oesel and Dago in the Gulf of Riga, which were captured by the Germans in the middle of October.

The thrust from East Prussia (Lyck area) and the Warsaw area of German-occupied Poland into Russian-occupied Poland and White Russia met with heavy Russian resistance, particularly in a pocket about 200 miles long and 100 miles wide, running from Bialystok to Minsk. In the course of this drive, German columns pushed forward a distance of about 250 miles in 9 days, or an average of about 27 miles a day.

It is important to note that the drive from the Warsaw area struck northeast from Brest Litovsk along the line Baranowicze-Minsk-Borisov Orsha, while the drive based on Lublin struck

through Luck, Rowne and Zhitomir, thus completely by-passing what may be termed the Pinsk area. This region of the Pripyat Marshes was probably not cleared of Russian resistance until about October 1.

The advance from the Lublin area aimed at the Ukraine met with heavy resistance in the vicinity of Luck and Novograd Volynski. However, the action in this sector is not comparable in scope with the fighting in the Bialystok--Minsk region. The Novograd-Volynski region was reached by the Germans after about ten days of fighting. This drive covered 200 miles, an average of about 20 miles a day.

The drive based on the Jaroslaw region of southern Poland and directed at Lvov and Tarnopol reached the vicinity of Tarnopol after about ten days of action. This push covered a distance of 150 miles, or an average of about 15 miles a day.

The Pruth--Dnestr drives against the Ukraine were balked by Russian offensive action at the outbreak of hostilities. Offensives in this region by Germany and her allies were of little significance until about the middle of July.

In terms of major thrusts by mechanized and motorized columns deep into Russian territory, the initial drive by the Germans seems to have come to a halt about July 2 or 3. The main significance of this lull probably lies in the necessity for consolidating the areas over-run by mechanized forces, for establishing stable lines of communication, and for destroying all Russian army units pinched off by encirclement tactics. While the Germans drove past Minsk within a week, the battle in the

sector extending roughly from Bialystok to Minsk lasted for 10 days longer. This pattern is characteristic of all the major offensives undertaken by the Germans during what has been termed the first phase of the campaign against Russia.

No definitive picture can be presented describing the nature of Russian fortifications in the western parts of the R.S.F.S.R., White Russia, or the Ukraine. It is probable that the German advance met with increased Russian resistance and a system of fortified zones roughly on the line Bobruisk--Novograd-Volynski--Proskurov. It has been reported that in the region of the Berezina River the Russian fortifications had an average depth of 20 miles, with a maximum depth of 70 miles east of Borisov in the direction of Orsha.

The Germans renewed their tactics of mechanized thrusts behind the Russian lines about July 9 or 10. At least three major drives can be clearly distinguished: Pskov--Ostrov; Vitebsk--Orsha; Kiev. In addition to the drives just listed, that through the Baltic States which took Riga about July 1 or 2 had its main force directed in a push through Estonia to the west of Lake Peipus.

The most important of these drives was the one which focused on the Smolensk area through Vitebsk, Orsha, and Mogilev. This drive was probably based on Dvinsk, Vilna, and Minsk. By July 17, German columns had driven past Smolensk toward Vyazma, a distance of over 200 miles from the Borisov region. This would seem to indicate an average rate of advance of about 30-35 miles per day. After the capture of Smolensk on July 16 or 17, the German forward thrust was checked, followed by a period of some

of the heaviest fighting of the campaign in the Smolensk sector.

The drive to the north in the western part of the R.S.F.S.R. seems to have been made up of thrusts with three separate objectives: Pskov, Ostrov, and Nevel. These drives made little headway while the major thrust in the Smolensk sector was in progress.

The heaviest drive in the Ukraine developed from the Novograd-Volynski sector in the direction of Zhitomir. This drive probably fanned out in the direction of Korosten. When it is recalled that the drive from Brest Litovsk was aimed in the direction of Baranowicze, it can be seen that the area of the Pripyat Marshes was completely by-passed. Another drive in the Ukraine toward Vinnitsa and Zherminka developed from the vicinity of Tarnopol. These main thrusts were coordinated with drives across the Pruth and Dnestr Rivers, the most important of which struck at Mogilev Podolski. By the twentieth of July, the Germans were operating in the Korosten and Zhitomir area.

2. The Northern Front (July 18 - December 6). The drive in the western part of the R.S.F.S.R. had as its main objective the effecting of a junction with German forces driving north and west of Lake Peipus. In addition, this offensive fanned out in four directions: (1) Nevel--Velikie-Luki, (2) Kholm, (3) Porkhov--Dno--Starya Russa, (4) Pskov--Solsti--Novgorod.

Russian resistance was particularly heavy in the Pskov and Porkhov sectors. There seems to have been a lull in the forward thrust of the drives east of Lake Peipus from about July 16 or 17 until about August 12. While the Germans made no

significant advance during this period, it is probably true that the area witnessed a good deal of heavy fighting. The pressure in the north toward Lake Ilmen was renewed about August 12 with Starya Russa, Novgorod, and Luga as immediate objectives. One column of German troops effected a junction in the vicinity of Narva with German forces driving through Estonia about August 18. This drive coincided with a break through in the Porkhov area toward Novgorod, which was taken by the Germans on the 21st of August, as were Narva and Kingisepp. Luga, a key point in the operations against Russian forces operating in the Leningrad area, was taken on August 26. This drive carried the Germans to within 100 miles of Leningrad. The operations which followed were directed at surrounding and capturing the city.

These operations were accompanied by a drive in Russian-occupied Finland toward Viborg and a drive toward the Svir River. The ring around Leningrad was tightened by a drive from Novgorod, cutting the Leningrad-Moscow railway and capturing Schluesselburg on September 8. The aim of effecting a junction with Finnish forces was not achieved, although the Finns captured Svirstroi on September 17. Following the virtual encirclement of Leningrad with the capture of Schluesselburg, there was heavy fighting in this part of the Northern Front until about September 25.

While these operations against Leningrad were going on, other German forces operating in the north were engaged in wiping out Russian resistance in Estonia. Tallinn was captured by the Germans on August 29 and by September 5 Estonia had been cleared of Russian resistance.

In the southern sector of the Northern Front, Velikie Luki was captured on August 27. The action in this sector later developed as a significant part of operations on the Central Front aimed at Moscow.

From about September 25, action in the Leningrad area can be characterized as siege operations. As early as September 13, the Germans claimed that railway guns were shelling Leningrad. The only major thrust in this area was that directed at Tikhvin early in November from Chudovo, a German base on the Moscow-Leningrad Railway. Tikhvin was captured by the Germans on November 8. This area was the scene of particularly heavy fighting until the beginning of the general German withdrawal early in December.

The German drive at the Valdai Hills from the Kholm and Velikie-Luki areas carried them to the vicinity of Lake Seliger. After an encirclement battle in this area lasting from about September 10 to 15, action in this sector settled down to defensive fighting on the part of the Germans.

In Finland, the other main area of the Northern Front, the campaign in its opening stages was divided into three operating fronts: (1) Petsamo--Murmansk; (2) Salla--Kandalaksha; (3) Viborg--Tulivara.

The German-Finnish advance toward the old Russian-Finnish frontier proceeded slowly toward Leningrad and east of Lake Ladoga and a continuous front from the Leningrad sector to the Murmansk sector was achieved about September 1. On September 4

the old Finnish frontier had been reached at all points on the Karelian Isthmus.

A new attack toward Murmansk in a general offensive between Salla and Lake Ladoga began about September 11, but these drives failed to achieve any spectacular results either in territory captured or Soviet troops destroyed. From about September 20 to December 15, the Finnish front was relatively inactive.

3. The Central Front (July 18 - December 6). The drive past Smolensk was stalled by July 25 with no decisive result achieved. The forward thrust of the drive probably came to an end about July 18. In this sector, the week from July 18 until July 25 was one of exceptionally heavy fighting, later developing into defensive warfare by the Germans. From July 25 until about August 10, the Germans withdrew from their advanced positions east of Smolensk, in the face of local counter-attacks by the Russians. With the development early in August of an all-out smash at the Ukraine, the German efforts in the Smolensk area, except for a drive at Roslavl, were confined to beating off localized Russian counter-attacks so as to stabilize the position and protect lines of communication being used to build up supply bases for a new advance toward Moscow. Further than this, large forces and great quantities of material had to be diverted to the Southern Front in the operations against Kiev in late August and throughout most of September.

Extensive preparations were undoubtedly made by the Germans for the offensive launched early in October on the Central

Front. It is highly probable, for example, that railway lines in the Smolensk area were in operation as early as the middle of August. While the daily supply requirements in this area from about the first of August until the first of October cannot be dismissed as inconsiderable, the scope of the renewed German operations in the center could only have been made possible through the building up of enormous quantities of reserve stocks in the Smolensk region.

The entire front can be described as stabilized by September 25. Most of the mechanized forces and the air fleet operating on the Northern Front were transferred to the Central Front. The Germans resumed large-scale offensive operations on the Central Front after the encirclement battle east of Kiev had been completed and heavy fighting on the Leningrad Front had ceased.

The attack on the Central Front began about October 2, probably with a heavy thrust at Orel. The Germans claimed that this drive covered a distance of about 100 miles in 36 hours. The loss of Orel was admitted by the Russians on October 8. In addition to this push, other drives that can be distinguished in this offensive are: (1) Bryansk and northeast; (2) Vyazma and southeast; (3) a thrust aimed at Borodino and **Mozhaisk**; (4) a push at Tula; and (5) a drive pivoting east of Velikie Luki and fanning out toward Rzhev and Kalinin. The timing of these drives cannot be clearly distinguished. It is suggested, however, that the stab at Orel might have served the purpose of drawing the Russians into a trap to be closed by the enveloping tactics of the swinging drives from Vyazma and Bryansk. This explanation would fit in

with the fact that the northern wing of the offensive -- the heavy push toward Rzhev -- was held back until the other drives were well underway.

By October 15, the Germans had reached Mozhaisk, a distance of about 160 miles from their base in the Smolensk area. This would represent an average advance of about 16 miles per day. The main concentration of German forces during this offensive, however, was in the Vyazma--Bryansk sector, seeking to crush the bulk of Timoshenko's forces. The drives to Kalinin, to Mozhaisk, to Tula, and east of Orel were stalled by October 20. This was possible, first, because the Russian armies were not annihilated (as claimed by Dr. Dietrich) in the Vyazma--Bryansk encirclement battle; and, second, because of the difficulty of maintaining lines of communication over distances of 150 to 200 miles, particularly in the face of the bad weather which hampered operations from about October 20 until November 15.

The fighting on the Central Front from about October 20 until the first of November was particularly heavy in the following areas: Kalinin, Volokolamsk, Mozhaisk, Naro Fominsk, Maloyaroslavets, Tula. No general offensive took place during this period. The only thrust of any significance was a breakthrough in the Maloyaroslavets area toward Serpukhov, and this can be characterized as a local operation.

German activity on the Central Front from October 20 until about November 15 can, in general, be described as aiming at the consolidation of territory over-run during the October offensive, with particular emphasis on the problem of developing

supply bases in the Moscow area, probalby at Staritsa, Rzhev, Mozhaisk, and Kaluga.

The final German offensive on the Central Front began on November 18 and was stalled by December 6. The new offensive can be said to differ in this respect from previous large-scale offensives in the Russian campaign: it was aimed at the capture of Moscow while the other offensives were designed to knock out Russian armed resistance. The offensive was composed of the following drives: on the northern wing toward Klin; in the center at Mozhaisk and Serpukhov; and in the south at Tula.

This offensive never achieved the momentum of previous drives; and, in this connection, the relatively short period between the conclusion of the previous offensive and the beginning of the new one may be of some significance. The point of furthest penetration by the northern wing was Dmitrov, about 60 miles from Kalinin. In the center, the Russians were pushed back in the Mozhaisk area, but the advance of the Germans was probably not more than 20 miles. The drive in the south by-passed Tula and then forked in the direction of Ryazan and Skopin. The thrust to Skopin carried the Germans about 90 miles past Tula, but this drive and that through Venev toward Kashira met with particularly heavy Russian resistance. The general withdrawal which followed the collapse of this offensive indicates that the weakness of German lines of communication was at least partially responsible for the failure to encircle and capture Moscow.

4. The Southern Front (July 18 - December 6). At the date of the command grouping of the German forces (July 18) the main

German drive in the western Ukraine was taking place in the Zhitomir region. Because of the by-passing maneuver around the Pripyat Marshes, the attack from the Novograd-Volynski area pivoted in the direction of Korosten, supplementing the main attack toward Zhitomir. The drive from the Tarnopol area in the direction of Zhmerinka and Vinnitsa was linked with attacks through Bessarabia and the forcing of the Dnestr River. The most important of the bridgeheads at the Dnestr was at Mogilev Podolski. The drive in the western Ukraine reached the Kiev area about July 18.

During the period of heavy fighting in the Smolensk sector, there was no major offensive in the south. The drive to destroy Russian resistance in the Ukraine got underway about August 2 with a thrust southeast of Kiev toward Belaya Tserkov, from the Zhitomir and Berdichev areas. This advance was linked with a drive down the Bug River from the Zhmerinka and Vinnitsa areas, and a drive down the Dnestr from the Mogilev Podolski area. All of these drives made an average advance of from 20 to 25 miles per day during the first week of the new offensive. The German thrust in the Bug area was aimed not only at Nikolaev but also at Krivoi Rog through a southeast fork of the drive from the Unan--Pervomaisk sector. By August 20 Odessa was under siege; Nikolaev had been captured (August 17); the Germans were close to Nikopol (southeast of Krivoi Rog) and to Dnepropetrovsk. This sweep to the Dnepr Bend made an average advance of from 15 to 20 miles per day. The mechanized spearheads of the Germans undoubtedly advanced more rapidly than this average rate of progress would

indicate. By August 26 or 27 the Russian bridgeheads on the Dnepr below Kiev had been destroyed, and the Germans had forced the Dnepr opposite Zaporozhe. This occupation of the Dnepr Bend area, with the exception of Odessa, marks the close of the first phase of the operations against the Ukraine.

The second phase of the Ukrainian offensive comprised two main operations: a drive southeast through Gomel toward Knotop and Poltava, and the forcing of the Dnepr in the Cherkasi--Kremenchug sector. Other offensive operations by the Germans were the fusing of the Dnepropetrovsk and Zaporozhe bridgeheads and the forcing of the Dnepr in the vicinity of Berislav in preparation for drives at the Perekop Isthmus and toward Melitopol.

The drive at Gomel from the Bobruisk area started about August 16 and resulted in the capture of Gomel on August 21. This thrust carried the Germans about 100 miles in 5 days. The Germans then held this area defensively in the face of local Russian counter-attacks for a period of about two weeks while the German positions in the Dnepr Bend were being consolidated. A new drive from the Gomel area was initiated by the Germans about September 3. The main force of the German effort was directed southeast toward Konotop while a second fork of the drive was aimed at Chernigov. By September 10 the Germans had established bridgeheads in the Kremenchug area and the drive southeast from Gomel had resulted in a deep salient northeast of Kiev toward Konotop in an effort to spring a vast encirclement trap on the Russian armies in the Kiev area. It may be of interest to note that during this phase of the Ukrainian offensive (about August 1

until September 10) the German forces operating in the Korosten sector west of Kiev fought defensively in the face of Russian counter-attacks, possibly in an effort to draw in large numbers of enemy forces. The drive on Kiev from the Chernigov and Korosten areas was timed with the junction of German forces 125 miles east of Kiev through the Gomel and Cherkasi--Kremenchug offensives. What may be called the "Kiev trap" was sprung about September 15. Kiev was ringed by German forces at the same time and captured about September 20. While the encirclement battle in this pocket was going on (September 15 to 25), other German forces captured Poltava.

On the lower Dnepr, the Germans, after many attempts, finally drove a bridgehead across the river in the Berislav area. This offensive then forked into two drives: one in the direction of the Perekop Isthmus and the other toward Melitopol. The objectives of these offensives were to prepare positions for thrusts into the Crimea and along the Sea of Azov toward Rostov.

Offensive operations in the Ukraine came to a halt about September 25 due to the necessity for a re-grouping of German positions along the entire front. The front at this time ran from the vicinity of Melitopol through Zaporozhe to Poltava and on a line to the east of Konotop.

The Germans resumed offensive operations on the Southern Front about October 2, at the same time that a major offensive was launched on the Central Front. The heaviest of the German drives were launched in the Donets sector from Kharkov to Taganrog. The main drives that can be distinguished are these: from the Melitopol area along the Sea of Azov through Berdyansk and Mariupol

to Taganrog; from the Dnepropetrovsk--Zaporozhe sector toward Stalino; from Poltava toward Kharkov; and from Konotop toward Kursk.

When compared with the previous Ukrainian offensives, two major points are to be noted in connection with these new drives: (1) the speed of the previous offensive was not achieved and (2) there is no evidence of the use of large-scale encirclement tactics. Whether this was due to adverse weather conditions, unfavorable terrain, difficult lines of communication, or more effective resistance by the Russians, or to a combination of all of these factors, cannot be stated.

The most rapid advance was made by the Germans in their push along the Sea of Azov. By October 20 the Germans had captured Taganrog, an advance of approximately 170 miles over a period of 18 days. The thrust aimed at Stalino covered about 120 miles during the same period. The drives on Kharkov and Kursk probably can be characterized as Slow Advances rather than as Major Pushes. In the former drive Kharkov was captured October 25 and Belgorod was captured about October 27. In the latter drive Kursk was not taken until November 3 or 4. From the nature of these operations it seems clear that the offensive against the Donets area was composed of a number of separate drives which were never integrated into a general offensive as in the operations in the Dnepr region.

While the large-scale offensive during this period on the Central Front failed to break Russian armed resistance in that

area, the offensive in the south did not develop into a generalized push; and as a consequence it seems likely that German offensive operations had to be revised. Having failed to end Russian resistance by the 20th of October, the new German military efforts on the Southern Front were framed in terms of achieving immediate territorial gains.

As a part of this change in strategy, the Germans undertook about October 20 to force the Perekop Isthmus in preparation for a drive on the Crimea. After meeting with heavy resistance for tendays, the Nazis broke into the Crimea about November 1; their offensive then forked in the directions of Simferopol and Kerch. The Germans encountered heavy Russian resistance in the vicinity of Sevastopol and Yalta, and in the region from Feodosiya to Kerch. From about November 7 until November 17, when Kerch was captured, German operations in the Crimea can be characterized as slow advances.

The control of the Crimea can be viewed as a first step in a German plan for an offensive against the Caucasus region. While the operations in the Crimea were going on (November 1 to November 17) the rest of the Southern Front can be described as relatively quiet. Following the capture of Kerch and Yenikale, the Germans launched a heavy drive toward Rostov in the Taganrog and Stalino areas. The only other offensive on the Southern Front was launched in the Kursk-Orel sector toward Voronezh. The main German effort resulted in the capture of Rostov about November 22. Russian pressure in this area took the form of heavy counter-attacks and the Germans were definitely on the defensive by November 29.

The collapse of this German effort aimed at the Caucasus forced a withdrawal on the Southern Front to a line running from Taganrog through Stalino, Kharkov, and Kursk.

C. Statistical Study of the German Campaign

Analysis of the German campaign in Russia provides a frame of reference for the statistical study of the campaign presented in this section. This statistical study is in turn the basis for estimates of military supply and transport requirements presented in Chapters II and III. The study includes a classification of German forces by type of division. Also, since the amount of supplies needed is related to the intensity and duration of fighting, the study includes a characterization of the types of combat in which the divisions were engaged as well as the number of days so engaged. Finally, as explained in the introduction to this chapter, these data are presented in terms both of the three fronts and of the eight time periods into which the campaign has been divided. The next three subsections define these statistical classifications of the German forces engaged in the campaign.

1. Germany Army Organization. The German military organization is a very flexible one.^{1/} It is constantly being shifted in order to exploit new techniques of warfare and to cope more successfully with changing combat conditions. Hence descriptions of corps, divisions, brigades, regiments, etc. should be considered only as typical rather than as universal throughout the army at any given time.

^{1/} For a complete discussion of German military forces, see Handbook on German Military Forces, TM 30-450 War Department, December 17, 1941.

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Basic units of the German army are the divisions. Most divisions are infantry, motorized or panzer units. There are in addition, large numbers of troops not organized in divisions. These other troops are ~~attached~~ to General Headquarters, though some are also assigned to a particular corps, to an army, or to army groups. Hereafter, all troops not in divisions will be referred to as "GHQ troops."

The German army is thought to consist of some 300 divisions. In the Russian campaign it is believed that as many as 195 divisions were used: 22 motorized, 18 panzer, and the remainder principally infantry. By the beginning of December, it is believed that the number of divisions on the Eastern Front was reduced to 160 and that the reduction was made primarily in the infantry divisions.

2. Types of Activity in German Operations. German activity on the Eastern Front has been classified according to intensity of combat into the following seven groupings:1/

a. Major Push. This type of action is meant to characterize the familiar advance movement of the German motorized and panzer divisions. The mechanized units are in attack, while the infantry may be regarded as being fundamentally engaged in a form of defensive action, involving a relatively small expenditure

1/ Thanks are due to Colonel Herman Kramer, Central European Section, Military Intelligence Division, for his assistance in developing these groupings of combat intensity. The designation of the type of fighting and its intensity could not be made to correspond with the action described in the Staff Officer's Field Manual (War Department FM 101-10) paragraph 93 page 175. However, the official figures constituted an important guide.

of ammunition. In a Major Push, infantry divisions usually operate well in the rear of the mechanized attacking units. In the drive southeast of Kiev, during the first days of the campaign, the various divisions involved in the action were strung out some 300 miles.

b. Heavy Fighting. This is the type of engagement in which the infantry attempts to attain and consolidate the advance positions of the panzer and motorized divisions. The infantry might be considered to be attacking; the panzer and motorized divisions to be in pursuit. It represents a period of active combat in which sooner or later all the units actively engaged are brought directly in contact with the enemy. Fighting in great depth occurs, leading to the establishment of a stabilized front. Such action is illustrated during the Russian counter-offensive after the fall of Smolensk.

c. Slow Advance. In this form of action, which is to be distinguished from a rapid enveloping movement, infantry divisions bear the brunt of attack, against a not too active enemy. Fighting in the Leningrad section during late August provides an example of the kind of action characterized as a slow advance.

d. Defensive Fighting. Three kinds of action are characterized as defensive fighting. The first two involve a slight withdrawal and regrouping of forces, either to draw in the enemy forces, which may thus be prepared for an encircling action as on the Kiev sector during the first two weeks of September, or to effect army regroupings as was done in the Central and Southern Fronts, from September 25 to October 7. Finally, "Defensive

Fighting" is used to describe the process of holding at one sector of a front while a Major Push is in progress on another sector, as in the Smolensk area, August 25 through September 25. Of the three basic types of division only the infantry is involved in defensive fighting.

e. Reconnaissance and Mopping-up. Mopping-up is the type of fighting in which the army cleans out small groups of the enemy left behind in the enemy's retreat. Examples include the fighting at the Pripyat Marshes from mid-July to September, and the mop-up in Estonia during late August and early September. All kinds of divisions are utilized for mopping-up operations.

f. Siege. This form of action, principally concentrated in the Leningrad area, primarily involves long-range artillery activity.

g. Inaction. This term has been used with reference to divisions temporarily withdrawn from the fighting front.

3. Time Periods in the Campaign. The eight periods into which the German campaign on the Eastern Front has been divided are described below.

a. June 22- July 17. This period, covering 26 days from the outbreak of war until the command grouping of the German forces into Northern, Central, and Southern Fronts, involved what may be termed a generalized push across the frontier with the main weight of the German effort ultimately directed against the Smolensk region. It is only with the conclusion of this period that German operations in Russia can actually be divided into Northern, Central, and Southern Fronts. It should be noted,

however, that such a division of German operations does not imply that after the command grouping of the German armies (von Leeb in the North, von Bock in the Center, and von Rundstedt in the South) there were three fully distinct theatres of operation in Russia. A consideration of the offensives launched by the Germans shows that no definitive geographical limits can be assigned to these sectors.

b. July 18-August 1. This period of 14 days was one of heavy fighting, particularly on the Central Front, coupled with preparations in the north for a drive on Leningrad and in the South for a major offensive in the Ukraine.

c. August 2-August 20. During this period of 19 days, German offensive operations on the Eastern Front were subordinate to a mechanized thrust by-passing Kiev and aimed at over-running the area of the Dnepr Bend. By August 20, this forward thrust had carried the Germans to most of the key-points in this area.

d. August 21-September 25. This period of 36 days covers two main offensives: the drive against Leningrad and the second phase of operations in the Ukraine which consisted of an attempt to encircle and destroy Russian armies operating in the south.

e. September 26-October 20. This period of 25 days involved two major offensives in the center and south, extending from October 2 until October 20. The first week of the period was devoted to a re-grouping of the German lines on these two fronts in preparation for the two offensives.

f. October 21-November 1. Hampered possibly by bad weather and stiffening Russian resistance, German operations during

this period of 12 days were a continuation of the offensives of the previous period, but at a very much reduced pace from the standpoint of forward advance. In contrast to the mechanized thrusts of the previous period, the bulk of the action involved heavy fighting by infantry units.

g. November 2-November 17. This period of 16 days was one characterized by defensive fighting, with the aim of consolidating positions captured during the October offensives. While thrusts to Tikhvin in the North and into the Crimea occurred during this interval, the main task faced by the Germans was that of building up stable lines of communication for the movement of stocks of supplies necessary for the launching of new offensives in the center and south.

h. November 18-December 6. This period of 19 days was one of major offensives in the center and south. By December 6, this German effort had been halted all along the front. The Germans were on the defensive in the Rostov area as early as November 29 and the withdrawal of German forces was a general movement along the entire front by December 7.

4. Statistical Summary of the Campaign. Total German forces engaged in the campaign are shown by type of division in Table 1. Table 2 gives a breakdown of the divisions according to the nature and duration of their activities. Finally, the data in Table 2 are summarized in Table 3 which shows the total number of days in which the various types of divisions were engaged in the various types of activity.

In these tables no attempt has been made to give estimates for any particular engagement as described in the analytical section because the necessary detailed information is lacking. Rather, the approach has been to average the forces involved in relation to the most significant military operations on each front. The tables are, therefore, an abstract picture of the German campaign, but it is believed that they provide a reasonably accurate basis for computing the supply requirements of the German forces in Russia from June 22 to December 6, 1941.

The belief in the reasonable accuracy of the totals given in the tables is strengthened by the fact that in the one instance where an independent check could be made, the margin of error was less than 10 percent from the overall estimated. Information available on the distribution of German forces on the Moscow Front from November 18 to December 6 made possible a detailed breakdown of this period of the campaign. The required tonnages of military supplies derived from this fuller breakdown deviated by less than 10 percent from the tonnages derived from the estimates in Tables 1, 2, and 3.

TABLE 1. GERMAN FORCES IN THE RUSSIAN CAMPAIGN

Period	Northern Front	Central Front	Southern Front
June 22 to July 17 (26 days)	38 Infantry 3 Panzer 4 Motorized	71 Infantry 9 Panzer 10 Motorized	46 Infantry 6 Panzer 8 Motorized
July 18 to August 1 (14 days)	33 Infantry 3 Panzer 4 Motorized	66 Infantry 9 Panzer 10 Motorized	41 Infantry 6 Panzer 8 Motorized
August 8 to August 20 (19 days)	33 Infantry 3 Panzer 4 Motorized	66 Infantry 9 Panzer 10 Motorized	41 Infantry 6 Panzer 8 Motorized
August 21 to September 25 (36 days)	33 Infantry 3 Panzer 4 Motorized	33 Infantry 3 Panzer 4 Motorized	74 Infantry 12 Panzer 14 Motorized
September 26 to October 20 (25 days)	31 Infantry 4 Motorized	63 Infantry 12 Panzer 10 Motorized	36 Infantry 6 Panzer 8 Motorized
October 21 to November 1 (12 days)	31 Infantry 4 Motorized	58 Infantry 12 Panzer 10 Motorized	31 Infantry 6 Panzer 8 Motorized
November 2 to November 17 (16 days)	31 Infantry 4 Motorized	58 Infantry 12 Panzer 10 Motorized	31 Infantry 6 Panzer 8 Motorized
November 18 to December 6 (19 days)	31 Infantry 4 Motorized	58 Infantry 12 Panzer 10 Motorized	31 Infantry 6 Panzer 8 Motorized

TABLE 2. ACTIVITY OF GERMAN FORCES IN RUSSIAN CAMPAIGN

Periods												
F R O N T	June 22 to July 17 (26 days)			July 18 to August 1 (14 days)			August 2 to August 20 (19 days)			August 21 to September 25 (36 days)		
	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys
N O R T H	28 Inf	MP	10	20 Inf	HF	3	20 Inf	HF	6	25 Inf	MP	12
		MU	6		MU	6		Re	5		Re	4
		HF	10	4 Mot	MU	6		SA	6		HF	20
	3 Panz	MP	10				3 Panz	MP	4	3 Panz	HF	12
	4 Mot	MP	10				4 Mot	MP	4	4 Mot	HF	12
		MU	5					Re	5		Re	6
	10 Inf	In	26	13 Inf	In	14	13 Inf	In	19	8 Inf	In	36
	3 Panz	In	16	3 Panz	In	14	3 Panz	In	15	3 Panz	In	24
	4 Mot	In	11	4 Mot	In	8	4 Mot	In	10	4 Mot	In	18
C E N T R A L	50 Inf	HF	8	40 Inf	HF	14	35 Inf	HF	10	20 Inf	DF	36
		MP	12	9 Panz	MP	5		DF	9	4 Mot	Re	10
		Re	6	10 Mot	MP	5	4 Mot	Re	10			
	9 Panz	MP	12		Re	5						
	10 Mot	MP	12									
		Re	6									
	21 Inf	In	26	26 Inf	In	14	31 Inf	In	19	13 Inf	In	36
	9 Panz	In	14	9 Panz	In	9	9 Panz	In	19	3 Panz	In	36
	10 Mot	In	8	10 Mot	In	4	6 Mot	In	19	4 Mot	In	26
							4 Mot	In	9			
S O U T H	30 Inf	HF	5	26 Inf	HF	9	31 Inf	HF	3	31 Inf	HF	15
		MP	15		Re	2		MP	12		MP	11
		Re	6		MP	3		Re	4		Re	
											MU	10
	6 Panz	MP	15	6 Panz	MP	3	6 Panz	MP	12	25 Inf	DF	12
	8 Mot	MP	15	8 Mot	MP	3	8 Mot	MP	12		MP	8
		Re	4		Re	5		Re	7		HF	10
											Re	
											MU	6
										12 Panz	MP	14
										14 Mot	MP	14
											Re	
											MU	10
	16 Inf	In	26	15 Inf	In	14	10 Inf	In	19	18 Inf	In	36
	6 Panz	In	11	6 Panz	In	11	6 Panz	In	7	12 Panz	In	22
	8 Mot	In	7	8 Mot	In	6				14 Mot	In	12

Note: For definition of type of activity see pp. 51-53

Abbreviations used in table are as follows:

HF = Heavy Fighting

MU = Mop-up

Inf = Infantry

MP = Major Push

Re = Reconnaissance

Panz = Panzer

SA = Slow Advance

In = Inactive

Mot = Motorized

DF = Defensive Fighting

(continued on next page)

TABLE 2. ACTIVITY OF GERMAN FORCES IN RUSSIAN CAMPAIGN (cont)

Periods												
F R O N T H C E N T R A L S O U T H	September 26 to October 20 (25 days)			October 21 to November 1 (12 days)			November 2 to November 17 (16 days)			November 18 to December 6 (19 days)		
	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys	No. and type of divi- sions	Type of acti- vity	No. of da- ys
N O R T H	12 Inf	MU	12	10 Inf	Si	12	10 Inf	Si	16	10 Inf	Si	19
		Si	13	10 Inf	DF	12	10 Inf	HF	3	10 Inf	HF	10
	8 Inf	DF	3	4 Mot	Re	4		MP	7		DF	9
		SA	15					Re	6	4 Mot	Re	12
		MP	7				4 Mot	MP	7			
	4 Mot	MP	5					Re	4			
		Re	4									
	11 Inf	In	25	11 Inf	In	12	11 Inf	In	16	11 Inf	In	19
	4 Mot	In	16	4 Mot	In	8	4 Mot	In	5	4 Mot	In	7
C E N T R A L	20 Inf	DF	6	40 Inf	SA	12	40 Inf	SA	16	40 Inf	Re	4
	50 Inf	Re	4	6 Mot	Re	6	6 Mot	Re	5		MP	8
		MP	7								HF	7
		HF	8							12 Panz	MP	8
	12 Panz	MP	7							10 Mot	MP	8
	10 Mot	MP	7								Re	4
		Re	6									
	43 Inf	In	6	18 Inf	In	12	18 Inf	In	16	18 Inf	In	19
	13 Inf	In	25	12 Panz	In	12	12 Panz	In	16	12 Panz	In	11
	12 Panz	In	18	4 Mot	In	12	4 Mot	In	16	10 Mot	In	7
S O U T H	10 Mot	In	12	6 Mot	In	6	6 Mot	In	11			
	16 Inf	DF	6	15 Inf	SA	12	15 Inf	HF	10	15 Inf	HF	10
	25 Inf	MP	8	5 Inf	HF	10		SA	6		SA	9
		Re	5		Re	2	4 Mot	Re	6	5 Inf	MP	4
		SA	6	4 Mot	Re	6		MP	6		HF	7
	6 Panz	MP	8				1 Panz	MP	6		DF	8
	8 Mot	MP	8				5 Inf	MP	6	6 Panz	MP	5
		Re	5					HF	10	8 Mot	MP	5
											Re	4
H	20 Inf	In	6	11 Inf	In	12	11 Inf	In	16	11 Inf	In	19
	11 Inf	In	19	6 Panz	In	12	4 Mot	In	4	6 Panz	In	14
	6 Panz	In	17	4 Mot	In	6	4 Mot	In	16	8 Mot	In	10
	8 Mot	In	12	4 Mot	In	12	1 Panz	In	10			
							5 Panz	In	16			

Note: Table continued from previous page. For definition of type of activity, see pp. 51-53 above. Abbreviations used in table are as follows:

HF = Fighting	MU = Mop-up	Inf = Infantry
MP = Major Push	Re = Reconnaissance	Panz = Panzer
SA = Slow Advance	In = Inactive	Mot = Motorized
DF = Defensive Fighting	Si = Siege	

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TABLE 3. DIVISION DAYS OF GERMAN FORCES IN RUSSIAN CAMPAIGN, JUNE 22 - DECEMBER 6, 1941

Type of division and type of combat	Total Division Days							
	Period I June 22- July 17	Period II July 18 - Aug. 1	Period III Aug. 2 - Aug. 20	Period IV Aug. 21 - Sept. 25	Period V Sept. 26 - Oct. 20	Period VI Oct. 21 - Nov. 1	Period VII Nov. 2 - Nov. 17	Period VIII Nov. 18 - Dec. 6
<u>Infantry</u>								
Major push	1,330	78	372	841	606	-	100	340
Heavy fighting	830	954	563	1,215	400	50	230	565
Slow advance	-	-	160	-	270	660	730	135
Defensive fighting	-	-	315	1,020	240	120	-	130
Reconnaissance	648	172	224	560	469	10	60	160
Siege	-	-	-	-	156	120	160	190
Inactive	1,222	736	1,026	1,404	1,187	480	640	760
<u>Panzer</u>								
Major push	228	63	84	168	132	-	6	126
Heavy fighting	-	-	-	36	-	-	-	-
Slow advance	-	-	-	-	-	-	-	-
Defensive fighting	-	-	-	-	-	-	-	-
Reconnaissance	-	-	-	-	-	-	-	-
Siege	-	-	-	-	-	-	-	-
Inactive	240	189	258	444	318	216	282	216
<u>Mo Motorized</u>								
Major push	280	74	112	196	154	-	52	120
Heavy fighting	-	-	-	48	-	-	-	-
Slow advance	-	-	-	-	-	-	-	-
Defensive fighting	-	-	-	-	-	-	-	-
Reconnaissance	112	114	116	204	116	76	70	120
Siege	-	-	-	-	53	-	-	120

CHAPTER II. SUPPLY REQUIREMENTS OF THE GERMAN ARMY IN THE RUSSIAN CAMPAIGN

A. Purpose and Methodology

Chapter I provided a great deal of the background information about the Russian campaign that is needed for an analysis of the German army's supply requirements on the Eastern Front during the June 22 --December 6, 1941 period. This chapter proceeds to one of the central tasks of the monograph: the actual estimation of those requirements.

The ultimate objective of the analysis was to ascertain the supply requirements of the German army on each sector of the front, for each period of the campaign, and for the campaign as a whole. The needs of the ground forces and the air force were considered separately, but in both cases, the first step was the making of an estimate of daily requirements.

Daily requirements of the ground forces were computed for the principal types of German division -- infantry, panzer, and motorized. Needs were estimated by categories: food, forage, clothing, ordnance, ammunition, fuel, and miscellaneous. From the standpoint of weight, the most important of these categories are ammunition, fuel, and ordnance.

In the case of certain categories it was necessary to differentiate between the requirements of active and inactive divisions, and in computing fuel and ammunition requirements it was necessary to proceed a step further and take into account the degree of activity, for requirements for both of these classes of material vary markedly under different types of combat conditions.

Once the daily supply requirements of each type of division were estimated for the various degree of activity, total requirements for the ground forces in the campaign on the Eastern Front could be readily computed by applying the data in Table 3 of Chapter I which showed the total number of days in which the various types of divisions were engaged in the various types of **activity**. Air force requirements were estimated separately and then added to the totals obtained for the ground forces.

B. Determinants of Supply Requirements

A number of basic factors, or determinants, must be considered in estimating daily supply requirements. The need for food and clothing, for example, is directly dependent upon the number of men in the TO. In computing requirements in other categories, it is necessary to consider such determinants as the fire power of divisions, the vehicular composition of divisions, and the distance supplies have to be carried from railheads to the front. It is worthwhile glancing briefly at each of these determinants before considering specifically what is involved in estimating supply requirements in each individual category.

1. Number of Men in the Theatre of Operations. The number of men in the TO, a basic determinant of food and clothing requirements, is not easy to estimate, even when one has a reasonably trustworthy picture of the number of divisions of each type in that area. The number of men in each type of division is known. Considering combat and service units, officers and men, there are approximately 16,000 men in an infantry division, 14,000 in a

motorized, division and 11,000 in a panzer division. But a German army of a given number of divisions has a much larger personnel than these figures would suggest. To achieve flexibility, GHQ troops -- including combat, artillery, engineer, reconnaissance, signal, medical, and supply units -- are assigned, as military developments necessitate, to particular armies, corps, divisions, or even parts of divisions. It is therefore impossible to estimate the exact number of men in a particular type of division at any given time; one cannot even describe an allocation which can be regarded as typical for a particular period. Partly on the basis of "specimen" allotments of GHQ troops (as indicated in the Handbook on German Military Forces) and partly on the basis of the number of men in similar organizations in the United States Army, it is possible, however, to estimate the total number of GHQ troops assigned to the TO. Although there is no reason to assume these troops will be exclusively allocated to the infantry, for the purpose of studying the problem of supply it was convenient and desirable to divide them among the infantry divisions. They increase the size of each such division by 11,000 men, to a total of approximately 27,000 men. The preponderance of all divisions are infantry divisions. Of the 195 divisions used in Period I, for example, all but 40 (22 motorized, 18 panzer) were infantry. The average number of men per division, therefore, works out to only slightly less than the average number of men here allocated to an infantry division, that is, approximately 25,000. This figure is quite generally accepted in military circles as

an estimate of the average number of men in a German field division.

2. Fire Power of Divisions. The fire power of divisions is a basic determinant of ammunition and ordnance requirements. It is possible to characterize the fire power of divisions by a description of the numbers and kinds of combat weapons. Tables 21a, 21b, and 21c in the appendix, supply this information for infantry, motorized, and panzer divisions, respectively. In table 21d, there is presented a corresponding breakdown for the 11,000 GHQ troops assumed to be allocated to each infantry division.

3. Vehicular Composition of Divisions. The vehicular composition of divisions is an important determinant of both fuel and ordnance requirements. Fuel consumption is obviously related to the number of vehicles of various kinds attached to each type of division. Because it is continually necessary to replace a certain proportion of both combat and supply vehicles, divisional vehicular composition is also an important determinant of ordnance requirements. The vehicular composition of infantry, motorized, and panzer divisions, respectively, is shown in tables 22a, 22b, and 22c in the appendix. Table 22d gives the corresponding information for the component of GHQ vehicles estimated to be assigned to each infantry division.

4. Distance Supplies Have To Be Transported. As is apparent, the distance supplies have to be hauled is an important determinant of fuel requirements. Supplies must be hauled by motor vehicles

from the advance railheads to the front. Throughout the Russian campaign there was an attempt to advance the railheads as the front moved forward. The longest average distance between railheads and the front for any period for any sector of the front was 250 miles -- the distance which prevailed on the central sector during the time of Germany's opening push. During the siege of Leningrad the advance railhead was pushed to within 20 miles of the front. During a number of periods, on each of the major sectors, the distance between railheads and the front was in the neighborhood of 50 to 75 miles. Because different types of trucks are employed in different stages of the haul between the advance railheads and the front, in estimating the fuel requirements of supply vehicles it was necessary to consider not the total distance involved but (1) the distance between the railheads and the distribution points and (2) the distance between the distribution points and the front. It has been assumed that during the entire course of the campaign motorized and panzer divisions operated, on the average, about 30 miles in advance of their distribution points; and that infantry divisions operated about 10 miles in advance. Because of the preponderance of infantry divisions, the average distance between distribution points and front-line troops works out to about 15 miles.

C. Ground Force Supply Requirements

1. Food. The food rations per soldier have not remained constant over the period of the Russian campaign. There is also some evidence that the Germans differentiate between rations apportioned to front-line troops and to other troops. It is not

certain, however, whether such differentiation was officially made on the Russian front. Furthermore, all such variations appear to have been made more with respect to kinds of food than to quantities. Hence the computations, based as they are upon a constant ration for all soldiers throughout the campaign, ought closely to approximate the quantity of food supplies involved.

A typical daily ration for one man at the front includes:

750 grams of bread
200 grams of meat
180 grams of peas and
other vegetables
120 grams Abendkost
40 grams of sugar
25 grams of drink
15 grams of salt.

This adds up to 1,330 grams, practically 3 pounds. The Abendkost (which is a combination of cold foods for the evening meal), the vegetables, and the drink, are in terms of dehydrated and/or compressed equivalents. One consequence is that the 120 grams of Abendkost shown (about 4 ounces) is much less than the bulk of food actually eaten for the evening meal. Similarly, much more liquid is consumed than the 25 grams indicated. Simple processing, perhaps involving nothing more than the addition of water, restores the food to normal proportions.

Converting rations per man to requirements per division, the following figures are obtained for daily requirements per division at the front:

<u>Division</u>	<u>Requirements per day</u>
Infantry and GHQ troops.....	40.5 tons
Motorized.....	21.0 tons
Panzer.....	16.5 tons

Somewhat smaller tonnages are required at the distribution points than actually go to the front. Bakery companies operating near the distribution points daily convert flour into bread. Since bread is approximately one-third water the 750 grams of bread served daily to each soldier require the transportation of only some 500 grams of flour, yeast, and salt to the distribution points. To some extent this decrease is offset by the conversion of livestock to dressed meat by slaughter platoons, which also operate near the distribution points. The percentage of dressed to liveweight for oxen is about 85; for sheep about 60; and for hogs about 78. By far the largest proportion of meat served is pork and pork products. The 200 grams of meat which the soldier gets thus require an average shipment of 265 grams on the hoof. Allowing for the changes in connection both with bread and meat, the total daily tonnage per division required at the distribution points to correspond to the figures already given for requirements at the front are as follows:

<u>Division</u>	<u>Requirements per day</u>
Infantry and GHQ troops.....	33.8 tons
Motorized.....	17.5 tons
Panzer.....	13.8 tons

2. Forage. The horses used by the German army are fed 4.5 kilograms of grain and 4 kilograms of hay per horse per day. This converts to a total of 18.7 pounds. Hay is bulky and ordinarily takes a great deal of space in shipment, but this factor has been disregarded, as it is known that the Germans put the ingredients they feed their horses into a preserved fodder which

can be very efficiently packed. On the other hand, it is not believed that this type of packing significantly affects the weight of the ingredients, so that weight calculations have not been modified to take account of it.

Horses are used only by infantry divisions. It is estimated that the 800-odd horse-drawn vehicles attached to an infantry division require the utilization of 3,800 horses. Forage requirements have been computed for this number of horses. The feed required by the livestock transported for food has then been estimated liberally, in order to allow for the livestock transported for other types of divisions as well as the infantry. On the basis of these two figures, it is estimated that forage requirements per infantry division amount to 38 tons daily.

3. Clothing. Little information is available on the rates of utilization of clothing by German troops in combat. However, the tonnage of clothing requirements is so small a figure relative to total tonnage that even appreciable errors in the clothing figure will have small influence upon the total supply picture. Rough approximations have been made on the basis of what is known about the total amount of clothing utilized by the German military services. Though it is true that in general clothing replacement can be delayed should the transportation situation or the supply situation make such a course necessary, there is evidence that clothing played a much more positive role in the campaign on the Russian front. The extension of military activity through several seasons of the year necessitated an important shift in the clothing

complement of each soldier. Unfortunately, there is no specific information on the quantities involved. For the purposes of this study, a rough approximation for daily requirements was made on the basis of "wastage factors" estimated by the British Ministry of Economic Warfare for the German army as a whole. The figures for annual replacements of both wool and cotton for military purposes suggest that an over-all figure of 1 ton per day per division can be used to cover replacements due to wear in the TO.

No extensive refitting of troops is believed to take place at the battle front. Hence it is assumed that no clothing is brought all the way to the front, and transportation tonnage is computed only as far as the distribution points.

4. Ordnance. As has been mentioned, tables 21(a-d) and 22(a-d) in the appendix, show the representative allocation of vehicles and guns for the various types of German divisions. Ordnance as here defined refers only to the supply requirements for these two types of materiel, the problems pertaining to ammunition being discussed separately below.

Basic material on ordnance was taken from United States Army ordnance specifications.^{1/} Though maintenance rates vary in accordance with the intensity of utilization in battle, the Ordnance Branch of the United States Army has felt that adequate account of these variations can be obtained by distinguishing the ordnance requirements of active and inactive divisions. The Army's figures are given for individual ordnance items and separately for

^{1/} Ordnance Major Item List, Part I, General Supplies with Maintenance Factors, Revised, September 15, 1941.

replacement parts of each item in detail. For the purposes of this study, it was sufficient to compute all ordnance entirely upon a weight basis. In order to avoid the very involved computations associated with estimates for replacement of particular parts of ordnance equipment, the decision was made to add an additional weight to the ordnance items themselves and to apply the maintenance figure to the total. A 10 percent additional weight for parts was therefore included.^{1/} In tables 21 (a-d) and 22(a-d), there are shown the weights of all guns and vehicles, the weights of replacement parts, and the replacement requirements in terms of both percentages and weight. The weight information is summarized below:

<u>Active divisions</u>	<u>Ordnance requirements</u>
	(tons per day)
Infantry and GHQ troops.....	36.3
Motorized.....	35.2
Panzer.....	59.2
<u>Inactive divisions</u>	
Infantry and GHQ troops.....	16.5
Motorized.....	14.5
Panzer.....	22.4

As examination of tables 21 and 22 reveals, the greatest percentage of the above tonnages is accounted for by replaced vehicles, both combat and supply. While the total amount of tonnage must be carried by rail to the advance railheads, from there to the

^{1/} This figure was suggested by Brig. Gen. James K. Crain, Chief, Field Service, Ordnance Department, United States Army. As a check, General Crain had the weight of replacement parts for typical ordnance items computed. The replacement parts weighed 10.7 percent of the ordnance items.

distribution points and the front the replacement vehicles could move up under their own power. The amount of fuel utilized by these vehicles over this distance is considered in the computation of tonnage in the section on fuel requirements.

The remaining ordnance equipment has to be moved forward from the railheads through the usual supply channels. Bringing these supplies to the front, therefore, involves a net addition to the hauling load. The tonnages of these replacements are given in the table below:

<u>Division</u>	<u>Ordnance replacement</u>
Infantry and GHQ troops.....	2.4 tons per day
Motorized.....	0.5 tons per day
Panzer.....	0.4 tons per day

5. Ammunition. The quantity of ammunition utilized by fighting divisions depends of course upon the degree of intensity of combat. In the United States Army the concept of "unit of fire" is used as a measure in making estimates for varying combat conditions. This figure tells the number of rounds (bullets or shells) assumed to be fired per day from each weapon in active combat. Multiples (less than or greater than 1) of the unit of fire are applied as the intensity of battle changes. One unit of fire per day for all guns in a division represents the ammunition utilized under active combat conditions.

In the present study extensive use was made of the unit of fire concept. Where figures on German arms were available, they were used. Elsewhere, computations were made on the basis of American figures for the corresponding weapon (or the most nearly corresponding one). These computations are given in detail

by divisions in tables 23(a-d), in the appendix. Due to variations in the number of weapons in corresponding organizations of the United States and German armies, the amount of ammunition expended in a unit of fire is different. Thus a United States triangular infantry division in a unit of fire would expend some 494 tons of ammunition. The corresponding figure for a German infantry division (without its complement of GHQ troops) is 727 tons of ammunition. For other types of German divisions the figures corresponding to 727 tons for an infantry division are: for GHQ troops, 625 tons; for a motorized division, 573 tons; and for a panzer division, 574 tons.

All our estimates of utilization of ammunition by German troops on the Russian front were based upon some percentage of the unit of fire. Action on that front was categorized into types of fighting prevailing over groups of days. The highest degree of utilization considered was one unit of fire each day for any stated group of days. It may of course be true that on a particular day of extremely intensive fighting more than 1, perhaps as many as 5, units of fire were actually expended. Indeed, it is the opinion of ordnance specialists that in occasional engagements it is only the limitation of supply that defines the limit of ammunition expended. However, fighting rarely continues at such a pitch of intensity for a number of days, and a breakdown of combat was made so that a properly averaged figure could be applied to groups of days as a whole.

The unit of fire has been assumed to be utilized by all three types of divisions under the conditions previously described

as "Heavy Fighting," and either this unit or fractions of it are utilized in other types of combat. Table 4 below gives daily ammunition expenditure, in terms of units of fire and tonnage requirements, for the three types of divisions under the various combat conditions described in chapter I. It is important to note that the expenditure of ammunition varies both in accordance with the intensity of battle and the type of division engaged.

Once daily ammunition expenditures are known, the requirements for each period of the Russian campaign can be readily computed on the basis of the analysis of the campaign in Chapter I and the tables at the end of that chapter.

TABLE 4. UNITS OF FIRE AND TONNAGE OF AMMUNITION PER DAY BY CHARACTER OF FIGHTING AND TYPE OF DIVISION

Character of fighting	Infantry and GHQ troops			Motorized		Panzer	
	Unit of fire		Tons/day	Unit of fire	Tons/day	Unit of fire	Tons/day
	Infantry	GHQ 1/					
Heavy fighting	1.0	0.67	1145	1.0	573	1.0	574
Major push	0.4	.27	460	1.0	573	1.0	574
Slow advance	.6	.4	686	-	-	-	-
Defensive fighting	.4	.27	460	-	-	-	-
Mopping-up and recon- naissance)	.2	.13	266	.2	115	.1	57
Siege	.05	.5	348	-	-	-	-

1/ Half of the ammunition required by GHQ troops is assumed to be expended in the vicinity of railheads, distribution points, etc.; the remainder, at the front.

6. Fuel. In estimating supply requirements, the fuel needed for both combat and supply vehicles must be included. As has already been pointed out, all types of vehicles attached to the divisions are used in combat, and large numbers of divisional and GHQ trucks are assigned to the task of bringing forward supplies from the railheads. It is not possible to indicate precisely how many of the trucks are allocated to combat and how many to supply service. On the basis of the scanty evidence available and what is known about the transportation needs of the German army, it is estimated that approximately 30 percent of the total number of trucks in the three types of divisions are used for bringing supplies forward. The GHQ troops have a relatively large number of trucks which are available for use whenever the supplies to be carried exceed the capacities of the divisional supply vehicles.

In computing fuel requirements, it is necessary to estimate the average fuel consumption of each type of vehicle, whether it be used in combat or supply, and the amount of fuel necessary to move all the vehicles in a given type of division 1 mile. Table 5 supplies this information; it will be noted that an additional 5 percent of weight was added to fuel tonnages to allow for the consumption of oil and grease. The fuel consumption figures themselves may appear low, but it must be remembered that they refer to European vehicles with lower horsepower and compression ratios than those with which Americans are familiar.

The consumption of petroleum by tactical vehicles has been computed on a basis which took into account the relative amount of utilization that vehicles of different types are given

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TABLE 5. CONSUMPTION OF PETROLEUM BY DIVISIONAL AND GHQ VEHICLES

Type of vehicle	Number of vehicles per division		Fuel consumption per vehicle Miles/gal.	Fuel consumption per mile				Total petroleum consumption per mile			
				Infantry and GHQ		Motorized		Panzer		Infantry and GHQ	
	Infantry and GHQ	Motorized		Gallons	Tons	Gallons	Tons	Gallons	Tons	Gallons	Tons
Trucks:											
Light	607	224	15	40.4	0.127	14.9	0.042	70.5	0.197	0.133	0.044
Medium	1632	1406	10	163.2	.527	140.6	.394	74.4	.203	.553	.414
Heavy	122	58	6	20.3	.063	9.7	.027	17.5	.049	.066	.028
Cars:											
Medium	109	88	18	6.0	.018	4.9	.014	25.6	.073	.019	.015
Heavy	46	-	15	-	-	-	-	-	-	-	-
Armored cars:											
Medium	-	-	3	-	-	-	-	17	.044	-	-
Heavy	3	25	2	1.5	.004	13	.036	14	.039	.004	.038
Motorcycles:	723	1400	40	18.1	.061	35	.118	25	.085	.064	.124
Tractors and half-tractors:											
Medium	157	420	2	79	.223	210	.588	159	.445	.234	.617
Heavy	40	30	1	40	.112	30	.084	-	-	.118	.088
Tanks:											
Light	-	-	2	-	-	-	-	140	.392	-	-
Medium	-	-	1	-	-	-	-	150	.420	-	-
TOTAL	3429	3651	-	-	-	-	-	-	-	1.191	1.368
											2.052

✓ An additional 5 percent has been added for lubes, grease, etc.

in the field.^{1/} The relative distances traveled by each type of vehicle was assumed to be constant. Thus, an auto was always assumed to travel 7.5 times as far as a medium tractor; light and medium trucks, 5 times as far; heavy trucks, 3 times as far, and so on. In order to ascertain the average mileages tactical vehicles are used per day under various types of combat conditions, these relative distances are then multiplied by a figure which gives consideration to the following three factors:

- (1) the intensity of combat
- (2) the movement of the front
- (3) the kind of division to which a vehicle is attached.

Table 6 gives the result of these computations. It shows the average number of miles per day tactical vehicles are used under various types of combat conditions. Vehicles attached to motorized and panzer divisions are grouped for the purpose of the computation; infantry and GHQ vehicles are also considered together.

¹ Information on this point is given in the Staff Officer's Field Manual (par. 88, p. 169).

TABLE 6. AVERAGE DAILY MILEAGE OF TACTICAL
VEHICLES IN VARIOUS TYPES OF ACTION

	Heavy Fight.	Major Push	Slow Adv. and Defen.	Mop-up	Siege	Inact.
<u>Infantry and GHQ Vehicles</u>						
Autos	100	125	75	112.5	26.25	18.75
Motorcycles	100	125	75	112.5	26.25	18.75
Trucks:						
Lt. & med.	67	83.3	50	75	17.5	12.5
Heavy	40	50	30	45	10.5	7.5
Armored Cars:						
Light	53	66.7	40	60	10.5	7.5
Tract. & half tractors:						
Medium	16	20	12	18	4.2	3.0
Heavy	13.3	16.7	10	15	3.5	2.6
<u>Motorized and Panzer Divisions</u>						
Autos	150	187.5		112.5		18.75
Motorcycles	150	187.5		112.5		18.75
Trucks:						
Lt. & med.	100	125		75		12.5
Heavy	60	75		45		7.5
Armored Cars:						
Medium	80	100		60		10.
Heavy	60	75		45		7.5
Tract. & half tractors:						
Medium	24	30		15		3
Heavy	20	26		12		2.6
Tanks:						
Light	24	30		18		3.
Medium	24	30		18		3.

trucks required for bringing the estimated supply requirements forward.

The above three factors represent the basic determinants of the amount of fuel needed for supply service. But two relatively minor sources of fuel consumption also had to be computed: (1) The amount of fuel consumed by ordnance vehicles which travel from the railheads under their own power; and (2) the amount of fuel required to convey the fuel needed for combat purposes and supply to the point of utilization.

For the campaign as a whole, gasoline utilization for all ground vehicles works out to 5.8 gallons per day per vehicle (of whatever kind). If the vehicles of inactive divisions -- 41 percent of all divisions over the course of the campaign -- are excluded from consideration, one gets a figure for the fuel consumption of vehicles belonging to divisions engaged in active fighting. These vehicles, it is estimated, burn up 9.1 gallons of gasoline per day.

7. Miscellaneous. Little exact information could be obtained on other necessary items of supply. Engineer supplies (including explosives, wire, and anti-tank mines, and many other types of materiel not considered in our computations in the section on ordnance) involve an expenditure which varies widely from period to period. As an over-all average, an additional 5 tons per division per day was used.^{1/} In modern mobile warfare it is believed that the materials used for makeshift housing on temporary

^{1/} This figure was suggested by the Corps of Engineers, United States Army.

As is obvious, total divisional fuel requirements for any type of activity may be obtained by multiplying the amount of fuel necessary to move all the vehicles in a division 1 mile by the appropriate figures in Table 6. Only 70 percent of the total petroleum consumed by trucks was used since, as has been previously stated, 30 percent of these vehicles are employed for supply functions. Total daily divisional fuel requirements (in tons) for each type of activity are shown below:

<u>Type of activity</u>	<u>Infantry and GHQ Troops</u>	<u>Motorized</u>	<u>Panzer</u>
Heavy fighting.....	49.86	47.38	95.75
Major push.....	74.51	91.85	119.69
Slow advance.....	38.48	--	--
Defense.....	38.48	--	--
Mopping-up (and reconnaissance)..	58.07	55.00	71.70
Siege.....	13.05	--	--
Inaction.....	9.67	9.19	11.97

To estimate the amount of gasoline required for supply services it was necessary to determine first the total tonnages of materiel which had to be moved to the front, an amount which, of course, is dependent on the number of divisions active or inactive on each sector during each period, and on the severity of the fighting. Secondly, the distance these supplies had to be moved (both from the railheads to the distribution points and from the distribution points to the front) was estimated. Third, as has been mentioned above, an allocation was made of the number of

fronts comprise the largest additional entry in the miscellaneous category. There is little objective data on the basis of which the required tonnages of all miscellaneous materiel can be computed; it is here assumed that the weight of such material is equal to about 5 percent of the weight of the supplies which have already been considered. This estimate involves the addition of supplies to an average weight of some 30 tons per day per division.^{1/}

8. Recapitulation. On the basis of the procedures which have been discussed, it was possible to compute the total tonnages required daily for the three principal types of division for any of the seven types of activity previously described. Moreover, differentiation could be made among quantities of supplies required at the railheads, at the distribution points, and at the front. The tonnages required to be delivered to the railheads for various types of activity are summarized in Table 7.

^{1/} In World War I, the figure for materiel in the miscellaneous category was much larger. Thus, the British Army, during the months from March 1 - August 31, 1918 (a period of relatively mobile warfare) transported 168 tons per day per 25,000 men of engineer supplies, railway constructions material, and macadam. (Figure from Report of Military Board of Allied Supply, v. 1, pt. 1, p. 544.) It is the opinion of the Corps of Engineers that in modern warfare there is little dependence upon a remote Zone of the Interior for supplies of railway and road materials. These would tend to be obtained near the point of use.

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TABLE 7. DAILY DIVISIONAL TONNAGES REQUIRED AT THE RAILHEADS FOR VARIOUS TYPES OF ACTIVITY

Type of Division	Item	Heavy Fighting	Major Push	Slow Advance	Defense	Mopping-up (reconnaissance)	Siege	Inactive
Infantry and GHQ	Food.....	Tons 33.8	Tons 33.8	Tons 33.8	Tons 33.8	Tons 33.8	Tons 33.8	Tons 33.8
	Forage.....	38.0	38.0	38.0	38.0	38.0	38.0	38.0
	Clothing.....	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Ordnance.....	35.1	35.1	35.1	35.1	35.1	35.1	16.5
	Ammunition..	1145.0	460.0	636.0	460.0	266.0	343.0	0.1
	Fuel L/.....	49.9	74.5	38.5	38.5	58.1	13.1	9.7
	Misc.....	61.1	51.4	39.0	27.7	18.0	22.1	3.8
	Totals.....	1364	694	871	634	450	491	103
Motorized	Food.....	17.5	17.5	-	-	17.5	-	17.5
	Clothing.....	1.0	1.0	-	-	1.0	-	1.0
	Ordnance.....	35.2	35.2	-	-	35.2	-	14.5
	Ammunition..	573.0	573.0	-	-	115.0	-	.1
	Fuel L/.....	47.4	91.9	-	-	55.0	-	9.2
	Misc.....	31.3	31.3	-	-	7.9	-	2.2
	Totals.....	705	750	-	-	232	-	45
Panzer	Food.....	13.8	13.8	-	-	13.8	-	13.8
	Clothing.....	1.0	1.0	-	-	1.0	-	1.0
	Ordnance.....	59.2	59.2	-	-	59.2	-	22.4
	Ammunition..	574.0	574.0	-	-	57.4	-	.03
	Fuel L/.....	95.7	119.6	-	-	71.7	-	12.0
	Misc.....	32.4	32.4	-	-	6.6	-	1.8
	Totals.....	776	800	-	-	210	-	51.0

L/ Combat only.

D. Air Force Supply Requirements

1. Number and Type of Planes. M. I. D. estimates that there were engaged on the Eastern Front at various times from three to five German air fleets. The following table shows their disposition on each major sector of the front in those periods into which, for the purpose of analyzing airplane supply requirements, it is convenient to divide the campaign:

<u>Front</u>	<u>Period</u>		
	<u>June 22 - Sept. 25</u>	<u>Sept. 26 - Nov. 1</u>	<u>Nov. 2 - Dec. 6</u>
Northern	1	-	-
Central	3	3	2
Southern	1	1	1

Though there is no fixed number of planes in a German air fleet, estimated allocations range upward of 600 planes (Handbook on German Military Forces TM 30-450, p. 329). There are also British and American estimates of total numbers of planes and breakdowns by types. The American estimates of total numbers are larger, primarily because of the inclusion of combat training planes used on or near the Eastern Front, but all estimates are consistent in regard to the percentages of planes of each type.

On the basis of all the available information, it is estimated that the Germans had the following numbers and types of planes on the Russian front as a whole in each of the three periods. Only active combat planes are included.

	<u>June 22-Sept. 25</u>		<u>Sept. 26-Nov. 1</u>		<u>Nov. 2 -Dec. 6</u>	
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>
Single-engine						
pursuit.....	650	19	520	18	390	19
Twin-engine						
pursuit.....	200	6	160	6	100	5
Bomber-dive (light).	500	15	400	14	175	9
Bomber-medium.....	1350	39	1080	37	850	42
Bomber-heavy.....	150	4	120	4	100	5
Transport and						
Army Co-op.....	600	17	600	21	400	20
Total	3450	100	2880	100	2015	100

2. Supply Requirements. In estimating ordnance, fuel, and other requirements for these planes, principal reliance was placed upon logistic data of the United States Army Air Corps. The basic source of information was a table prepared by the Statistics Section of A-4 on January 1, 1942, and called "Thirty Days Supply for Operating Tactical Airplane." Necessary adaptations were made so that the figures would apply to German airplane models.^{1/} For fuel consumption, for example, the correspondences indicated in the accompanying table were utilized, with correction factors as given there:

^{1/} The correspondence between American and German models has been established in A-4.

<u>Type plane</u>	<u>American model</u>	<u>German equivalent</u>	<u>Fuel correction factor for German planes 1/</u>
Single-engine fighter	P-40 P-39-D	ME-109-F FW-198	1.00
Twin-engine fighter	P-38-E	ME-110	0.96
Dive bomber	A-24	JU-87-B	1.20
Light bomber	A-20-B	DO-215	0.74
Medium bomber	B-25 B-26	JU-88-B JU-88-A	0.64 0.70
Heavy bomber	B-24 B-17	HE-177 F.W.Kurier	1.07 1.08

In general, the correspondences between German and American models shown in the table were also assumed to hold for the bombs and ordnance carried by these planes.^{2/}

The bulk of the bombs and ordnance carried by airplanes was assumed to be brought to the air fields by truck. To compute the fuel required for this service, all airplanes were considered to be based at a point one-quarter of the distance from the rail-head to the front during any combat period. It is believed that this rough estimate will average out the following three factors:

1/ Fuel consumption of the American plane, multiplied by the correction factor, gives the estimated consumption of the German equivalent.

2/ Such exact correspondences do not, in fact, hold between all the sets of paired planes, but it is believed that the differences tend to offset one another, so that on the whole the assumption is not misleading. The superiority in armament of the P-38-E over the ME-110, for example, is offset by a corresponding inferiority of the P-40 as compared with the ME-109-F. Explicit exception to the assumed correspondence was made in two cases. The bomb load of the F. W. Kurier is taken to be the average of the B-17 and B-24, while that of the JU-88-B is estimated to be two-thirds that of the A-20-B.

(1) that dive bombers and some of the short-range pursuit planes are fairly close to the front

(2) that heavier bombers and some of the pursuit planes are probably close to the supply depots at the railhead

(3) that some fuel is required for transport at the airdromes themselves.

In any case, the fuel consumed in moving supplies is a small percentage of total daily tonnage requirements. Even if all supplies for airplanes had to be hauled the entire distance from the railhead to the distribution points, the fuel requirements for the carriers would amount to less than 3 percent of the total daily tonnage requirements of the air force.

The food and clothing needs of the air force personnel were estimated in accordance with the same formulas and figures used in estimating the corresponding requirements of ground troops. In determining the number of men in the air force it was assumed that each plane requires roughly 50 men. This figure includes flight personnel, supply and salvage people, mechanics, and other field personnel.

Materiel replacements were estimated as 5 percent of the total tonnage per plane. It is included in the summary figure given below.

On the basis of the above estimates of the number and distribution of combat planes during each of the three periods, and the daily requirements for each plane and for the air force personnel, it was possible to compute the total tonnage required daily to supply the air force on each front. These computations are

summarized in the accompanying table. Roughly, the requirements average out to 1 ton per plane per day.

TABLE 8. THE AVERAGE DAILY TONNAGE REQUIREMENTS FOR THE GERMAN
AIR FORCE ON THE RUSSIAN FRONT ^{1/}

(Tons per day)			
Front	June 22--Sept.25	Sept.26--Nov.1	Nov.2--Dec.6
Northern	629		
Central	2013	2013	1394
Southern	865	917	727
Total	3507	2930	2121

^{1/} As the preceding discussion suggests, the table summarizes the requirements needed for combat planes only, and makes no allowance for the supplies needed for combat training planes. In the three time periods used for the airplane supply study, it is estimated that there were, respectively, some 2050, 1600, and 1500 such planes with the fleets on the Eastern Front. Supplying them would have added about 33 percent to the tonnage burden in the first two periods and 42 percent to the burden in the third period.

E. Summary

By utilizing the tonnage data which have now been given for both the ground forces and the air force (see Tables 7 and 8), and the information about the campaign summarized in the tables at the end of chapter I, it is possible to determine supply requirements for the entire German army on the Eastern Front, for each of the three major sections of the front and for each of the eight periods into which the campaign has been divided.^{1/} Table 9 gives this information, and shows total supply requirements for the entire campaign. As will be seen, it is estimated that the German army and air force required 16,648,000 tons for the entire campaign, or approximately 100,000 tons per day for the 167 days of the campaign.

Table 10 presents a breakdown of these daily figures by fronts and by periods. It will be noted that the highest daily consumption rate occurred on the Central Front in the second period, during the Smolensk campaign (July 18 - August 1), when some 73,000 tons were needed daily. The minimum requirement, 13,000 tons per day, was experienced on the Northern Front between October 21 and November 1.

^{1/} As was mentioned in the discussion of fuel, additional computation is necessary to determine the fuel consumed in carrying supplies from the railheads to the distribution points and from the distribution points to the front. On the average, this requirement amounts to an additional 3 percent.

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TABLE 9. TONNAGES REQUIRED TO BE DELIVERED AT THE RAILHEADS
FOR GROUND AND AIR FORCES PER FRONT PER PERIOD

(thousands of tons)									
Front	Periods								Total
	I June 22- July 17	II July 18- Aug. 1	III Aug. 2- Aug. 20	IV Aug. 21- Sept. 25	V Sept. 26- Oct. 20	VI Oct. 21- Nov. 1	VII Nov. 2- Nov. 17	VIII Nov. 18- Dec. 6	
Northern	765	303	410	1,047	362	155	240	323	3,605
Central	1,531	994	785	530	1,201	469	616	885	7,011
Southern	854	480	638	2,327	531	263	429	510	6,032
Total	3,150	1,777	1,833	3,904	2,094	887	1,285	1,718	16,648

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TABLE 10. DAILY TONNAGE REQUIREMENTS FOR ARMY AND AIR FORCES IN THE RUSSIAN CAMPAIGN

(thousands of tons)		Periods								
		I June 22- July 17	II July 18- Aug. 1	III Aug. 2- Aug. 20	IV Aug. 21- Sept. 25	V Sept. 26- Oct. 20	VI Oct. 21- Nov. 1	VII Nov. 2- Nov. 17	VII Nov. 18- Dec. 6	
Front										
Northern		30.1	22.3	22.2	29.7	14.5	12.9	15.0	17.0	
Central		60.9	73.0	43.3	16.7	50.1	41.1	39.8	47.9	
Southern		33.7	35.2	34.4	65.5	22.1	22.9	27.5	27.6	
Total		124.7	130.5	99.9	111.9	86.7	76.9	82.3	92.5	

In Table 11, the average daily requirements per division of the ground forces are estimated. As is shown in this table, the highest daily requirements per division were 835 tons per day, needed in the Smolensk campaign on the Central Front between July 18 and August 1. This action involved 85 divisions for the 14-day period. On each of the fronts during the various periods, daily requirements ranged, at times, well over 800 tons; while there were some periods when activity was such that much lower figures prevailed. Thus on the Central Front from August 21 to September 25, requirements shrank to 370 tons a day, and no more than this amount was required on the Northern Front in the period from October 21 to November 11. The overall (weighted) average tonnage consumed, per division per day, emerges as approximately 575 tons.

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TABLE 11.- AVERAGE DAILY TONNAGE REQUIREMENTS PER DIVISION

(tons per day)								
PERIOD								
	I June 22- July 17	II July 18- Aug. 1	III Aug. 2- Aug. 20	IV Aug. 21 Sept. 25	V Sept. 26- Oct. 20	VI Oct. 21- Nov. 1	VII Nov. 2- Nov. 17	VII Nov. 18- Dec. 6
Front								
Northern	650	540	540	730	410	370	430	490
Central	660	835	490	370	565	490	480	580
Southern	550	620	610	650	420	490	600	600

CHAPTER III. TRANSPORT ON THE EASTERN FRONT

A. Character and Significance of Transport Facilities

The preceding chapter presented estimates of the quantities of supplies needed by the German armies in Russia up to December 6. The primary task of the present chapter is to determine how these supplies were transported.

The chapter also attempts to indicate the relative adequacy or inadequacy of the facilities available, and to suggest how the relationship between the available transport capacity and the expenditure of supplies may have acted as a limiting factor on strategy and tactics. It is well to bear in mind, however, that the influence of the supply problem on strategy and tactics may be largely hidden from view, since the observed magnitude of the German effort may itself reflect an adjustment in initial German plans. This, conceivably, may explain the approximate equivalence between estimated supply requirements and transport capacity which the present chapter indicates. Nevertheless, as noted later, it is possible that at certain times the rate of expenditure of supplies at the front exceeded the long-haul transport capacity available and hence necessitated a precedent period of inactivity in which stores could be accumulated at nearby bases. A detailed examination of the means by which supplies were carried to the German armies in Russia at various times, and of their capacity, might therefore reveal that the supply problem was a major factor in determining the timing or direction of certain tactical maneuvers; and it might also provide information of value

in appraising the possible magnitude and timing of German operations in Russia during 1942. Time did not permit such analyses to be included in the present study, which deals with the supply problem in more general terms, but much of the information required for an intensive analysis of the effect of supply considerations upon strategy is assembled here.

B. Transport Facilities Available

The Germans had available for use in Russia five types of transportation: intercoastal shipping, inland waterways, air transports, motor vehicles, and railways. Of these, the railways alone have been the object of intensive analysis. Coastal and inland shipping are not believed, on the whole, to have attained great importance in the period under consideration. Air transport is thought to have been used only for the needs of the air force and for quantitatively unimportant emergency operations. And motor vehicles, as already indicated, are designed mainly for tactical uses, to carry supplies over the comparatively short distances from advance railheads to the front, and for other short-haul communications purposes in the areas adjacent to the field of combat. It is true that heavy trucks and large motor trailers have been provided under GHQ command which are available, in case of necessity, for long-haul traffic. But for various reasons, including, especially, Russian road conditions, these vehicles would ordinarily be used only to supplement the more tactically useful and reliable railways.

The capacity of the railways is, therefore, the core of

the supply problem on the Eastern Front. Consequently, in the following pages there are considered, successively, the extent and character of the network captured and converted by the Germans; the number and capacity of trains which they may have been capable of operating over this trackage; the relationship of these estimates to supply requirements; and requirements for rolling stock. Finally, some consideration is given to the extent to which diversion of rolling stock to military use may have impinged on the economic efficiency and the military potential of Europe. A further factor -- the availability of personnel for the operation and administration of military trains -- has not received detailed consideration because it is believed to possess a greater inherent flexibility than the other limiting factors, such as rolling stock, and, consequently, to be of subordinate importance.

C. The Captured Rail Network

1. Character of the Lines. By the end of November 1941, it is estimated that the Germans controlled some 37,000 kilometers of Soviet railroads, of which about 25,000 were within the 1938 boundaries of the U.S.S.R. Of these, a large proportion were unsuitable for military transport either because of inadequate port facilities at terminals or because of their circuitous routes. It is estimated that the Germans utilized some 15,500 kilometers of roads in order to support their operations.

These 15,500 kilometers were distributed among 8 lines, of which 2 may be further subdivided, making 10 in all. It is these routes, and these routes alone, which are presumed to have

been used in supplying the troops.^{1/} The lines and the nature of their trackage are listed in Table 12.

TABLE 12. RAIL LINES PRESUMEDLY USED BY THE GERMANS

Rail Line	Nature of track	Stretches of single track (kilometers)
I. Königsberg--Tilsit--Riga--Valga--Pskov	Single	-
II. Warsaw--Mosty--Polotsk--Velikie-Lukie	Single	-
III. Warsaw--Bialystok--Grodno--Vilna--Dvinsk--Pskov	Double	25
IIIa. Warsaw--Bialystok--Baranowicze--Minsk--Borisov--Smolensk	Double	60
IV. Königsberg--Kaunas--Minsk--Bobruisk--Gomel	Double	-
V. Riga--Dvinsk--Polotsk--Vitebsk--Smolensk	Double	86
VI. Warsaw--Brest-Litovsk--Pinsk--Kalinkovichi--Gomel	Single	-
VII. Lublin--Kowel--Berdichev--Kazatin--Kiev	Double	38
VIIa. Lublin--Kowel--Korosten--Kiev	Single	-
VIII. Jaroslaw--Lvov--Zhmerinka--Odessa	Double	90

^{1/} See map, page 17 . The map also shows certain other routes which the Germans might have used for special purposes but which were not deemed suitable for major supply lines and hence were not included as part of the basic supply network. Chief among these are the 6 following: 1. Tallinn--Kingisepp. 2. Narva--Pskov. 3. Libau--Plavinas--Novosokolniki. 4. Lvov--Tarnopol--Shepetovka--Korosten--Zhlobin. 5. Lvov--Mogilev-Podolski. 6. Iasi--Tighina--Razdeinaya.

Thus it is considered that there are four single-track lines and six double-track lines used by the Germans to supply the Eastern Front. The table shows that five of the six double-track lines have single-track stretches. These stretches are chiefly in the neighborhood of the 1938 Russian frontier and they probably did not greatly impair the efficiency of the roads, especially as they could be converted to double track in case of necessity. However, they may have imposed some limitations on capacity.

One of the single-track lines, No. VI, runs through the Pripyat Marshes, which were by-passed in the German military advance and in which Russian resistance continued until a late date. It is believed, therefore, that this line was not available to the Germans until after September 25.

2. Conversion of Gage. The 9 (later 10) lines which the Germans presumably used were not found by them ready for immediate operation. It must be recalled that the German roads, and consequently the vast majority of German rolling stock, are of standard gage (4 ft., 8-1/2 in.), while the Russian roads and rolling stock are of the broad 5-foot gage.

There are at least four means by which the Germans could have adapted the Russian lines to their use: by reloading freight to broad-gage rolling stock at the border; by equipping their own rolling stock with adjustable axles; by using interchangeable trucks on their rolling stock; and by converting the Russian lines to standard gage.

The first of these solutions would pose an almost insur-

mountable obstacle to the achievement of the rapid system of supply required by the military machine. Nor is it likely that the Germans had broad-gage rolling stock in sufficient quantity to carry the goods needed. The Russians certainly destroyed or evacuated most of their own rolling stock, and the Germans themselves had only an insignificant amount of broad-gage equipment. The first solution may therefore be safely rejected.

It is believed that the next two solutions were equally impracticable for the Germans. They did not possess either adjustable axles or interchangeable trucks (which are hard to operate and really unsatisfactory) in sufficient quantities to equip the tens of thousands of cars and locomotives needed to meet the requirements of the Russian campaign. Furthermore, the use of adjustable axles and interchangeable trucks is complicated in practice, and on the scale of the German railway operation in Russia, would have introduced difficulties so great that it is believed that these types of equipment were resorted to, if at all, only in the very first days of the war, until actual conversion of the lines could be carried out.

It is the fourth means, then, which the Germans are thought chiefly to have used to make the Russian railroads available for their purposes. Though at first glance the conversion of Russian lines to standard gage might appear the most forbidding solution, it is actually the one which involves the minimum of technical difficulties.

Under ideal conditions a crew of 25 men can reduce broad

to standard gage at the rate of about a mile and a half per day. Switches, frogs, and cross-overs, which require cutting and re-joining of rails and switch-bars, present the only difficult problem. Again under ideal conditions a crew of five men following the first gang could make these changes at the same rate.

On the Eastern Front, however, conditions were hardly ideal. It must have been difficult, if not impossible, to transport a full number of crews and their supplies to the advanced sections of the line. In the latter stages of the advance, snow and general cold weather were probably severe handicaps. Roadbeds probably suffered considerable damage as a result of military action and sabotage. Frogs and switches must also have presented special problems. In the United States they are usually designed to fit the conditions met at the particular points where they are to be used. If the Germans attempted to manufacture frogs and switches of standard specifications, it is probable that their use entailed additional work in filling, grading, cutting, etc. In other words, if the frogs and switches are not made to suit the line, the line must be made to suit them.

In view of these factors it is impossible to make more than an arbitrary estimate of the speed with which the Germans converted the Russian lines to standard gage. The figure of 40 man-days per mile, it is believed, would probably allow for all of the difficulties which were encountered.

As noted above, the Germans are thought to have been faced with the task of converting some 15,000 kilometers of road,

of which roughly 60 percent was double-tracked, raising the total on a single-track basis to about 25,000 kilometers, or 15,000 miles. At the estimated figure of 40 man-days per mile about 600,000 man-days would be required to convert the ten lines included in the study. Stated another way, 1,000 crews of 30 men each could do the job in 20 working days. This should not have been a difficult requirement to meet. Nor is it probable that the repair or establishment of watering and coaling stations would present a serious problem.

Concerning repairs to bridges the situation is more dubious, and there is not enough information available to support estimates of the size of the reconstruction task. It is true that the Germans claim to be especially expert in reconstruction of damaged steel bridges. American railway men would use timber for temporary construction, and they estimate that, under emergency conditions, a trestle on piles of moderate size could be put up in three weeks. The Germans had plenty of suitable lumber in Eastern Poland. It consequently seems clear that, in one way or another, the bridges have been restored to use.

Absolute accuracy is not claimed for these estimates. They do, however, give some picture of the order of magnitude of the task, from which it appears that the conversion and reconstruction of the Russian roads was not by any means an insurmountable problem for the Germans. Especially in view of the importance of the work, the labor required is small. And since no particularly difficult technical problems are involved, it can only be con-

cluded that the Germans were able to complete conversion of the railways so that they could carry the major burden of supply on the Eastern Front.

D. Train Capacity of the Captured Network

The problem of estimating accurately the maximum carrying capacity available to the Germans over the converted rail routes presents great difficulties. Specifically, the task is one of determining the number and the capacity of trains capable of being dispatched over each of the routes in question. These are not unrelated variables, since, within certain limits, an increase in the one can be balanced by a decrease in the other, without much change in the actual tonnage carried over the line. Where information is obtainable concerning both the load capacities of available locomotives and cars and the physical characteristics of the lines over which they are to be run, it is possible to calculate with reasonable accuracy the theoretical capacity of the road; this can then be modified in the light of known factors affecting operating efficiency.^{1/}

For the purpose of estimating the capacity of the railroads in Western Russia under German operation there is available reasonably satisfactory information on the capacity of the locomotives and cars that would be used. But information is not available concerning the rail lines themselves and hence it is not possible to calculate the theoretical capacity in the usual way. Instead, 30-car trains of a fixed net load (480 short tons

^{1/} A list of the principal factors is given in the appendix.

per train) have been assumed, as detailed in a later section, leaving determination of the number of such trains that could be run as the sole problem. For this purpose it has been necessary to make some admittedly questionable assumptions concerning the application of experience elsewhere to conditions in Western Russia, and to draw broad inferences from slim evidence as to the characteristics of the railroads and the conditions of war-time operation in Russia.^{1/}

We are informed that on an unimproved single-track line in the United States one might well find the maximum traffic density was not greatly in excess of 10 trains a day in each direction, and it seems reasonable to take this as a minimum figure under normal operating conditions, for any of the single track lines under consideration. Support for this assumption is found in the fact that in the early 1900's, during the Russo-Japanese war, the Trans-Siberian railway, which was then single-tracked and certainly not "improved" in the sense used here, carried 12 trains a day in each direction -- presumably a capacity load; and also in the fact that the Archangel railway, which was relatively unimportant before the German invasion, carried some 9 small trains a

^{1/} Fortunately, the advice and assistance of a number of railway experts was available. But since the information they provided, or the views they expressed, may have been inaccurately reproduced, it is thought better not to give individual credit at every point. Rather, we should like to acknowledge that much of the material on railways in the present chapter was based on discussions with Messrs. McClain and Akers of the Southern Railway, Col. Herman Kramer of G-2, Col. Frank S. Ross of G-4, Mr. Ernest Williams of the Transportation Section, National Resources Planning Board, and Mr. Ernest Ropes of the Dept. of Commerce.

day,^{1/} a figure which, it was thought, could be considerably increased.

The opposite extreme (by way of setting an upper limit) may be taken as the maximum density that could be achieved over a fully improved line, under ideal operating conditions. On one such line in the United States, after installing sidings every 4 or 5 miles and lengthening them to accomodate two trains, developing elaborate block signalling, and using more powerful locomotives, the operation of 27 trains a day became possible. Under similar conditions in Europe, according to one authority, as many as 45 trains a day might be operated each way. Allowing for the smaller size of cars and capacity of trains in Europe, this does not appear to be inconsistent with the lower United States figure, and has therefore been accepted as the standard of perfection.^{2/}

The problem, therefore, now becomes one of determining where within the range of 10 to 45 trains a day in each direction one may find a reasonable figure for average German performance on Russian single-track lines. Performance on double-track lines is usually taken as 2 to 3 times that on a single-track line of comparable quality.^{3/} To strike a fair average it is necessary to

^{1/} Supply Routes from the United States to the Russo-German War Zone, Eastern European Division, COI, pp. 59-60.

^{2/} For short periods of one or more days performances up to 85 trains a day in each direction on single-track lines have been recorded, but these are of interest only because of their exceptional character.

^{3/} The higher factor is apparently not applicable to the highest single-track densities. Thus, 90 trains a day in each direction would appear to be about a maximum for regular double-track operation.

assemble and evaluate the available evidence with respect to
(a) the pre-war status of railroads in Western Russia, and (b)
operating conditions in war time.

1. Pre-war Status of Railroads in Western Russia. It
has been impossible to obtain direct evidence concerning the
characteristics of the railroads captured by the Germans. The most
relevant information is that contained in the report^{1/} of Mr. Ralph
Budd who, with a staff of engineers, surveyed the entire Russian
railroad system in 1930. The report cites the following as flaws
found in the permanent way throughout Russia:

- (1) Ties too small (5-inch instead of 7).
- (2) Ties too far apart.
- (3) Too many humps and dips in grade, causing strain on couplers.
- (4) Changes of grades at the entrances to bridges were frequently too sharp.
- (5) Poor ballast, mostly sand
- (6) Rails not well anchored against "creep"--lengthwise movement of rail.
- (7) Track layout in terminals frequently bad.

The Budd report has little to say concerning the weight
of rails used on Russian lines. From another source,^{2/} however,
information has been obtained which shows that on six of the ten
main lines under consideration the weight of rails fell in the
range 62-67 pounds (per yard). The exceptions were:

Brest-Litovsk--Baranowicze--Minsk--	
Orsha--Smolensk--Vyasma	77 pounds
Kiev--Dnepropetrovsk (east of Koristova only)	77 pounds
Zhmerinka--Kiev	91 pounds
Zhmerinka--Odessa	91 pounds

^{1/} Report on the Railroads of the U.S.S.R., 1930. All references
here are to Volume I; Volume II has not been accessible.

^{2/} A special source, believed to be reliable.

These weights are, in general, light. On American main-line roads 90-110 pound rails are standard, and still heavier rails are used on our lines of densest traffic.^{1/}

Information on grades and curves is similarly unsatisfactory. In 1927 grades of 3/4 of one percent to 1 percent were found in western Russia. While grades of this order should not be classified as difficult, it is perhaps of some significance that the AEF^{2/} used "pushers" on such grades during the World War. On curves no specific information of value is now available.

Signals are of prime importance for efficient railway operation. In 1930 the Soviet signalling system was very backward by our standards, and it is understood that even now, on many lines, the tower and bell system is used. This is a primitive block system in which signals are operated manually and communication between the signalmen in charge of the several blocks is carried on by means of electric bells; if the necessary labor is available, however, this system is deemed to work efficiently.

The foregoing factors are adverse to high traffic densities since they tend, collectively, either to force the use of shorter, more lightly loaded trains, to reduce train speeds, and to increase delays in terminal; or to cause break-downs and other stoppages, rapid wear of rails, damage to roadbed, and, in general,

^{1/} Heavy trains can be run over light rails, but would cause eventual deterioration. This long-term factor is not believed to have affected German operations.

^{2/} References to AEF experience are drawn from Wilgus, W. J., Transporting the AEF in Western Europe, Columbia University Press, 1931.

an increased maintenance burden.

Since 1930 the Russian railways as a whole have been greatly improved, but one wonders whether as much attention was paid to the railways in the west as to those in central Russia, the south, and the east. The latter regions are those which, for both strategic and economic reasons, were probably developed most rapidly; it is unlikely that resources were devoted to extensive railway improvements throughout the west. Allowing, however, for some reconstruction, and also for the fact that the adverse factors noted were of relatively slight importance in the first place, it must be concluded that these factors cannot be accorded a heavy weight.^{1/}

Another consideration which argues against taking too pessimistic a view of the capacity of Russian railroads is the statement by several observers that Russian railroads generally have the highest traffic density in the world. The sparseness of their railroad network has forced them to resort to various devices -- notably the provision of passing sidings at frequent intervals -- which permit a high traffic density. The silence of the Budd report on the question of passing tracks suggests that they were deemed adequate even in 1930. While the above evidence suggests that the Russian railroads should be placed somewhere near the top

^{1/} Terminal facilities are a possible exception. Because of their shortage of rolling stock, it is understood, the Russians took drastic measures to prevent cars from lying idle, and they met with little interference from passenger traffic. They may thus have been under little compulsion to bring their terminal facilities up to standards found desirable in other countries.

of the range of 10 to 45 trains a day in each direction over single-track lines, it is probable that a figure nearer the middle is likely to accord more closely with achieved average densities. The figure of 45 trains a day is understood to represent a theoretical capacity under ideal operating conditions, and it is thought unlikely that such conditions would generally obtain over the 15,000 miles of track under consideration. It is perhaps instructive, in this connection, to note that densities over four separate sections of the double-tracked Trans-Siberian railway early in 1941, when there was presumably great pressure to run the line at capacity, ranged from a low of 15 to a high of 50 trains a day in each direction.^{1/} Even the latter figure is believed to be substantially less than the theoretical capacity of a line as good as the Trans-Siberian, which is reputed to be the equal in every respect of the best lines in other countries. It is concluded, therefore, that 25-30 trains a day in each direction probably represented the practical capacity of single-track lines in western Russia; and that the corresponding figure for double-track lines was in the vicinity of 70-75 trains a day.^{2/}

2. Railroad Operations in War-time. Several factors cause the conditions of railroad operation in a theatre of war to differ from those in time of peace. Adverse effects arise from damage to the permanent way and fixtures and from direct interferences with normal train operation; these are offset in part by the disappearance of civilian services, which interrupt, and decrease

^{1/} United States Military Attaché at Moscow.

^{2/} Evidence received since the completion of this study tends to confirm the belief that the east-west lines in Western Russia had relatively low traffic requirements before the war and had therefore probably not been greatly improved to increase their capacities.

the efficiency of, goods transport.

It is not known to what extent railroad installations were damaged by military action or by the Russians before their withdrawal. Direct evidence of widespread damage to cities and industrial plants, extensive land-mining, and the like make it probable that the scorched earth policy was applied to vital railroad facilities. In addition, there would be the injury incidental to artillery and air attack, tank operations, and so on, concerning the extent of which there is no direct evidence.

Damage to bridges and fills may have proved especially troublesome. Although the Germans, as noted earlier, appear to be adept in the reconstruction of bridges, two points are clear: (1) substantial delays would be involved in such reconstruction and (2) the temporary structures probably erected in most instances would not be capable of carrying heavy loads, with the result that train speeds, and perhaps train loads, would have had to be reduced. Similarly, wherever a substantial amount of refilling must be done it takes upwards of six months for the mass to consolidate. During this period trains must be operated at low speeds.

The net effect of factors like those mentioned above is difficult to evaluate, since there are other, independent, reasons for running trains at uniform low speeds -- perhaps as low as an average of 12 miles an hour between sidings, with a top running speed of 16-20 miles an hour -- and since these uniform low speeds are feasible where there is no need to provide for fast passenger traffic or other high-speed trains.

Actual or prospective damage to the communications system of the railroads is perhaps the most important way in which train operations are retarded in a theatre of war, since it is not necessary to score a direct hit by a shell or bomb in order to knock down wires or otherwise disrupt the signal system. This is as true of the Russian tower and bell system as of any other. In fact, the danger of interference with the signal system by the military or by guerillas and saboteurs is so great that trains operated where such danger existed would probably be run without the benefit of block signalling arrangements, since the failure of a signal, once dependence on it had been established, would cause more serious traffic delay than a total absence of signals. This was the experience of the AEF. If the Germans dispensed with the Russian signal system, they may have regulated trains by flagmen, torpedoes, and flares, and by running trains at low speeds, head-to-tail, with a substantial reduction in operating efficiency. Where blackout conditions had to be observed, night operation (especially switching) would be rendered still more difficult, and sometimes, perhaps, impossible. Because the less rugged construction of European cars causes them to suffer damage at speeds as low as 5 miles an hour, speeds at which cars often collide in shunting yards in the U.S., European train dispatchers might be expected to be exceptionally cautious where there is any danger of collision.

Terminal operations, which have an important bearing on peace-time efficiency, are less likely to exert a restrictive

influence during war. Thus, although the Russian facilities may have been inferior by American standards (which call for yards and sidings capable of accomodating a full 24 hours' capacity) they may have been quite adequate for military needs, unless seriously damaged. As a rule, military trains are unloaded in a matter of a few hours, without regard to storage of the goods. Not only is it desirable to keep the cars moving, but large accumulations of freight cars are conspicuous and vulnerable to attack. If trains can be unloaded in, say, 5 hours, then the capacity of the terminal yards and sidings need be only sufficient to accomodate the number of trains that would be expected to arrive in this period of time. If a schedule of one train an hour was being followed, therefore, the terminal would need to accomodate only 5 trains. Under pressure, furthermore, unloading time can usually be reduced; on the other hand, blackout conditions and adverse weather are likely to delay unloading and result in crammed terminals if there is no excess capacity.

Although little specific information is available, a review of the elements that have been discussed reveals that their adverse effect upon German railway operations in Russia will be greatest immediately following German acquisition of the lines, and over those portions of the track lying closest to the actual combat area. On those sections of a railroad line which have just been converted, and which lie within 100-200 kilometers of the front, in all probability train operations will be very much less than the maximum. One further retarding factor, which has not

hitherto been mentioned, is the unfamiliarity of train crews with the grades, curves, bridges, yards, etc. Another is the need to establish repair and maintenance facilities; if German locomotives of the Consolidated type were to be used, for example, it would be necessary to establish repair-pits, since these locomotives must be serviced from underneath. Finally, coal and water stations would have to be put in order or established, and if the local water supply was hard, softening equipment would have to be brought in. While one may be confident that German plans took all those items into account, it is apparent that time considerations as well as proximity to the front must be taken into consideration in assessing the effectiveness of German railway operations.

In view of the foregoing factors, it has seemed advisable to make use of two estimates. The first applies to the period (of 2 or 3 weeks, as a rule) immediately following German capture, and to those portions of line which lie within 100 or 200 kilometers of the fighting front. Over these sections, which are considered to lie between a major base and an advance railhead, train operation is believed to have been extremely difficult, and traffic density is therefore estimated at the low figure of 10 trains per day in each direction on single-track lines and 30 trains a day on double-tracks. This, then, is the daily number of trains available to make deliveries to the advance railheads.

As time passed and the front moved further east as reconstruction work was completed and operating conditions became

more normal, a figure approaching more nearly to the peace-time densities probably became achievable; still, temporary bridges, unconsolidated fills, imperfect adaptation of locomotives, rolling stock, and personnel to the idiosyncrasies of the Russian lines, and so forth, would, in the opinion of this study, have prevented full attainment of maximum schedules, notwithstanding the absence of passenger traffic, commercial freight, and other peace-time obstacles. The figure for train operation ultimately achieved over those sections of the line more remote from the line of battle and ending (for the purposes of the study) at the major bases, has therefore been estimated at 20 trains a day in each direction over single-track lines and 60 over double. While heavier densities were no doubt attained over certain lines, or at certain times, the above figure is believed to be representative of conditions on the German-operated Russian roads as a group.

It must be observed, however, that the transition from the low level of operations on the advance sections to that given above for train movements into major bases could not be effected all at once, and that allowance must be made for this fact. The statistical computations given below, therefore, use figures of 15 and 45 trains a day to represent the average number of trains run to the major bases in each of the eight periods of the campaign, instead of 20 and 60 trains, since the better level of operation was presumably not attained until at or near the end of the campaign.

By way of conclusion, it may be pointed out that the U. S. Staff Officers Field Manual gives 20 trains a day in each direction as the standard of performance for single-track lines; and that Mr. Ernest Williams expressed the view that under the very worst conditions it should be possible to run 12 to 15 trains a day in each direction on a single-track line and 25 on double-track routes; under somewhat more favorable conditions single-track operation should approach the level of 20 to 25 trains a day in each direction.

E. Tonnage Capacity

With figures for the number of trains per day and the number of lines which are available to the Germans, three further steps are necessary to reach an estimate of the tonnages of supplies which the Germans could deliver by rail to the advance railheads and to the major bases. It is necessary to estimate (a) the tonnage capacity of a typical military goods train, (b) the number of troop trains required, and (c) the service freight allowance.

1. Capacity per Train. As indicated earlier, the problem of estimating the size and capacity of the typical German military train is not difficult.

The average rated capacity of German freight cars in 1938 was eight metric tons per axle. Since some 97 percent of German cars were two-axle cars at that time, the average rated capacity was about 16 metric tons per car. Actually, in 1938, a year of heavy traffic and general overloading, the achieved

average load was only 12 metric tons per car.

In 1918 the Allied Board of Supply considered ten metric tons to be the practical capacity of the standard Continental car. Although cars built since then have run to larger capacities (up to 20 metric tons or more) the persistence of a large number of the older, pre-war cars has kept the average down.

It is further the opinion of railway men in this country that overloading of cars is really very unprofitable, even as an emergency measure. In their opinion it inevitably leads to breakdowns and derailments which far outbalance any possible advantage that might be achieved by the temporarily increased capacity.

The study has consequently presumed 14.5 metric tons, or 16 short tons, as the average practical capacity of the present German car. While other European cars may be used in Russia, the best of them conform closely in size and capacity to those of Germany. For technical reasons, cars of similar characteristics will be used so far as possible.

The number of cars per train is also reasonably well known. There is some evidence that 30 cars per train is standard Germany military practice.^{1/} This figure is in conformance with what is known about German commercial operation. In 1938, for example, the average number of cars per freight train in Germany was about 35. If allowance is made for the fact that this average

^{1/} It so happens that American railwaymen consider trains of 30 cars to be the most practicable length for military trains under conditions here. Owing to the much larger cars, the total capacity would be very much greater.

includes a substantial number of empty or incompletely loaded cars, whereas military trains tend to be fully loaded, a figure of 30 cars per military train is seen to be not too low.^{1/} The gross weight per train (and load on the locomotive) of 30-car military trains would come to about 800 (short) tons, compared with an average weight of slightly over 700 tons per commercial train in Germany in 1938. The net load, or tonnage carrying capacity, of a military train of 30 cars is 480 tons -- the figure used in this study.

Before considering the question of troop trains it may be well to remark in passing that the maximum tonnage capacities of trains are pretty well determined by physical limitations which cannot be quickly circumvented. Even if excess motive power is available and the character of the roadbed and length of sidings permits the operation of heavier trains, attempts to increase the tonnages hauled either by overloading cars or by increasing the length of trains are likely to be unprofitable even as emergency measures. Overloading individual cars brings immediate penalties in the form of journal breakdowns and wheel breakage. Overextending the length of trains necessitates excessively troublesome bracing, to prevent sudden shifting and jolting of the load when the train stops or starts; it is also likely to cause breakdown of the draft gear (coupling). European freight cars, with their

^{1/} Further confirmation of this figure is found in a recent count of German military trains (mixed troop and materiel) passing through Austria; the average for some 1200 trains was 32 cars each. Troop trains generally are longer than materiel trains.

primitive coupling arrangements (a three-link chain thrown over hooks and tightened with turnbuckles until the pneumatic buffers are in contact) are particularly subject to this limitation.

2. Troop Trains. It must be remembered that not all of the cars on all of the trains moving over the captured roads to the front lines were available for freight. Some must have been used for the transportation of fresh troops up to the front; others were required for the movement of the sick, the wounded, and the men on leave back to the rear areas.

In estimating the number of trains necessary to bring up new troops, it has been presumed, in the absence of direct evidence, that 60 divisions were carried in each direction by rail over the 10 lines -- a number sufficient to replace one-third of all the divisions on the Eastern Front. If it is assumed that 70 trains were required to move each division, a total of 4,200 trains would then have been needed during 125 days, or 33.6 trains per day.^{1/}

Concerning trains required for the sick, it is presumed that some 3 million men were exposed to the severe living conditions on the Eastern Front, and that, among them, the incidence of illness was 1.5 per cent per month, or 45 thousand cases per month. Of these cases, it is believed that one-third, or some 15 thousand men per month, would have required evacuation. Thus,

^{1/} The total number of days in the period studied is 167. It is presumed, however, that divisional movements, transport of the sick and wounded, and leaves were not considerable early in the campaign, and a figure of 125 days is therefore used.

over the 125 days, some 60 thousand cases, or 2 per cent of the whole number of men, were probably moved to the rear over the captured lines.

This figure is for non-epidemic illness only. There is no reliable information concerning the incidence of epidemic disease, nor can it reasonably be estimated. The allowance for movement of the sick is therefore confined to non-epidemic cases. For these 60 thousand men about 150 hospital trains, each carrying 400 men, would be required, or 1.2 trains per day over the 125 days.

It has further been assumed that perhaps 750 thousand men were so wounded in battle as to require evacuation by train. This would call for 1,875 trains, or 15 trains per day.

The final category for which an allowance is necessary is that of men on leave. It is presumed that, by the end of the period under study, one-fourth of the 4,500,000 troops on the Eastern Front, or 1,125,000 men, had been given leave and required railway transport from and back to the front. At 1,200 men per train, these 1,125,000 trips would have required 937.5 trains during the 125 days, or 7.5 trains per day.

The summary for the trains needed for the movement of personnel then is:

Divisional movements.	33.6	trains	per	day
Hospital trains:				
Sick.	1.2	"	"	"
Wounded	15.0	"	"	"
Men on leave	7.5	"	"	"
Total number of trains per day needed for personnel movements	57.3	"	"	"

In view of the inevitably imprecise nature of this calculation, the figure has been rounded to 55 trains per day.

3. Service Freight. A further allowance is necessary for service freight carried by the roads. This is ordinarily limited to coal, maintenance items, and the like. Such freight represented 9 percent of the total ton-kilometers hauled over the German roads in 1938.

Under the circumstances obtaining on the Eastern Front, however, such a figure is believed to be very much too low. Numerous factors require an increase. The fuel haul, for example, is much greater on routes east of Warsaw than in Germany, the nearest fuel supplies being in Upper Silesia. A considerable amount of boiler water would also probably have to be hauled by rail, especially in the regions south of Zaporozhe. Timbers, piles, and steel for repairs and construction on the railroad lines themselves must have been brought up in quantity, as well as additional timber for platforms, warehouses, and other auxiliary structures. Finally, some hauling of ballast was necessary, though such hauls would probably be short.

In view of these factors, a figure of 20 percent of train capacity or supplies carried, whichever was lower, has been taken as a just allowance for service freight over the captured lines. A similar estimate was given independently by one of the railway experts consulted.

With these figures it is possible to reach a net estimate for the total capacity of the lines to carry German military

supplies both to the major bases in the rear and the advance railheads nearer the front lines.

It will be recalled that, in the early part of the campaign, the Germans had 3 single-track lines at their disposal. Using the estimates arrived at in an earlier section, these would have been able to carry 10 trains each per day to the advance railheads. The 6 double-track lines would have been able to carry 30 trains each per day. The total trains per day to the advance railheads would thus have been 210. But 55 of these would have been needed for personnel movements, leaving 155 per day for freight. Each of these having 30 cars, and each car having a capacity of 16 tons, the total daily tonnage would have been 74,400 tons. From this 20 percent must be deducted for service freight,^{1/} leaving a net tonnage to advance railheads in the period before September 25 of 59,500 tons per day. After September 25, however, another single-track line was added to the rail network available. This increased the gross daily tonnage to advance railheads to 79,200 tons per day, and the net tonnage to 63,400 tons per day.

The tonnage capacity of the transport facilities to the major bases farther from the lines of battle was much greater. Before the end of September, the 3 single-track lines, with 15 trains per day each, would have borne 45 trains per day, and the double-track lines, with 45 trains per day each, would have carried 270 trains per day -- a total of 315 trains per day. Again deduct-

^{1/} No allowance was made for service freight for cars used for divisional movements, hospital trains, or trains carrying men on leave.

ing the 55 trains per day needed for personnel movements, a net of 260 trains per day served the major bases. With 30 cars each, and a capacity of 16 tons for each car, the gross tonnage would have been 124,800 tons per day. A 20 percent deduction for service freight yields 99,800 tons per day as the average net tonnage that could be carried each day to the major bases in the early period.

Later, when the extra single-track line was added, the gross tonnage to major bases was increased to 132,000 tons per day, and the net tonnage to 105,600 tons per day.

The smaller capacity of the roads serving the advance railheads, as compared with those serving the major bases, should not be considered without recalling the fact that the supply requirements at the advance railheads were also less (see Chapter II). On the major bases falls the burden of meeting the needs of all the troops and machines other than those actively engaged in the fighting at any given time. The latter, of course, must depend on the advance railheads.

The table which follows shows the daily average tonnages estimated (in Chapter II) as having been utilized at the major bases and advance railheads in each of the eight major periods of the campaign, compared with the daily average train capacities estimated above.

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TABLE 13. DAILY AVERAGE GERMAN TONNAGE REQUIREMENTS AND RAIL CAPACITY ON THE EASTERN FRONT,
BY MAJOR PERIODS
(thousands of tons)

	Period I June 22- July 17	Period II July 18- Aug. 1	Period III Aug. 2- Aug. 20	Period IV Aug. 21- Sep. 25	Period V Sep. 26- Oct. 20	Period VI Oct. 21- Nov. 1	Period VII Nov. 2- Nov. 17	Period VIII Nov. 18- Dec. 6
Delivery of Supplies to Major Bases								
Maximum rail capacity.	1/	125	125	125	132	132	132	132
Less 20 percent for service freight.	-	25	25	25	26	26	26	26
Maximum available capacity for military supplies.	-	100	100	100	106	106	106	106
Tonnage required at major bases.	-	131	100	112	87	77	82	53
Surplus or deficit per day.	-	-31	0	-12	19	23	24	13
Deficit as percent of maximum available capacity (percent).	-	31	-	12	-	-	-	-
Delivery of Supplies to Advance Railheads								
Maximum rail capacity.	1/	2/	74	74	79	79	79	79
Less 20 percent for service freight.	-	-	15	15	16	16	16	16
Maximum available capacity for military supplies.	-	-	59	59	63	63	63	63
Tonnage required at adv. bases.	-	-	85	95	74	65	70	79
Surplus or deficit per day.	-	-	-26	-36	-11	-2	-7	-16
Deficit as percent of maximum available capacity (percent).	-	-	44	61	17	3	11	25

1/ It has been assumed that there were no railhauls in the first period, and all supplies were carried by divisional and GHQ trucks.

2/ There are assumed to be no advance railheads in this period.

F. Supply Requirements and Rail Capacity

Examination of the table shows -- if the estimates are approximately correct -- that in nearly every period it was possible for the Germans to carry by rail all the supplies required at the major bases but that additional facilities -- presumably motor vehicles -- were consistently needed for the movement of supplies to the advance railheads. It is, of course, possible that the estimates are in error and that rail capacity was at all times sufficient; but the error can also work in the other direction, and it therefore seems advisable to take the figures in the table as representative of actual requirements and of the capacity of the 10 main rail lines to deliver them. Since, moreover, it is not believed that other railroads, inland waterways, or inter-coastal shipping were used extensively, attention will be focused on the use of motor vehicles in conjunction with the accumulation of reserve supplies to overcome rail deficiencies.^{1/}

The ability of the German army's motor vehicle supply to handle the estimated railway deficits depends not only upon the tonnages to be hauled, as shown in the table, but also upon the distance to be covered. This distance, as has been indicated before, is much less from the major base to the advance railhead than from the initial supply bases at the edge of the ZI to the major base. A smaller truck capacity, therefore, is required to transport a given tonnage forward from the major base than is

^{1/} Attention should perhaps be called to the fact that no account has been taken in this study of the tonnages involved and the facilities required in shifting troops between fronts. This may at times have been a large task.

required to bring it up to this point. Also, the conditions of operation -- roads, the state of administrative organization, blackouts, unfamiliarity with the country, repair and wrecking facilities, etc. -- are likely to be much less satisfactory in the vicinity of the advance railheads. Together, these considerations suggest that smaller and more flexible motor vehicles will be used in carrying supplies to the advance railheads than in bringing them up to the major bases.

The problem of transporting supplies forward from the railheads to the combat area was discussed in Chapter II and allocations of trucks for this service were made. In the total complement of vehicles available to the divisions, as shown in Tables 22a, through 22d. (Appendix, Chapter I), provision must also be made for moving men and equipment along the front. When allowance has been made for both these services, a residuum of trucks, particularly heavy trucks (of 5-ton capacity) and trailers (30-ton) remains. These are available for long-distance hauling. They can thus be used to supplement the railways, either in the haul from the initial supply bases at the edge of the Zone of the Interior (Warsaw, etc.) to major bases or from major bases to the advance railheads.

The bulk of these residual trucks comes from the numbers allotted to GHQ troops in Table 22d. It can roughly be estimated that for each group of 11,000 GHQ troops at least 50 heavy trucks and 36 trailers remain for long-distance hauling. From available German reports, it appears that trailers organized

in trains of 1000-ton capacity are used mainly in the long haul from the initial supply bases to the major bases. The following table presents figures showing the length of haul and the estimated number of days required to make the round trip, as well as the tonnage to be carried by motor vehicle (i.e., the rail deficits from the table on page 122). From these data there are computed the number of trailers or trucks required and this number is given, together with the percentage that this represents of the total number of "residual" trucks estimated to be available for this supplementary long-haul service.

TABLE 14. TRUCKS NEEDED TO MEET RAILWAY TRANSPORT DEFICIT FROM MAJOR BASES TO ADVANCE RAILHEADS.

Period	Haul (kms.)	Days per trip	Rail deficit (tons per day)	5-ton truck deliveries required per day	Trucks needed	
					Number	percent of trucks available
I ^{1/}						
II ^{2/}						
III	150	0.75	25,240	5,084	3,813	22%
IV	300	1.50	35,610	7,122	10,683	62%
V	300	1.50	10,320	2,064	3,096	19%
VI	150	0.75	2,080	416	312	2%
VII	150	0.75	6,560	1,312	984	7%
VIII	150	0.75	15,260	3,052	2,289	16%

^{1/} It has been assumed that there were no rail hauls in this period, and that all supplies were carried by divisional and GHQ trucks.

^{2/} It is assumed that there were no advance railheads in this period.

TABLE 15. TRAILERS NEEDED TO MEET RAILWAY TRANSPORT DEFICIT
FROM INITIAL SUPPLY BASES TO MAJOR BASES

Period	Haul (kms.)	Days per trip	Rail deficit (tons per day)	30-ton trailer deliveries required per day	Trailers needed	
					Number	percent of trailers available
I ^{1/}						
II	750	2.5	30,640	1,021	2,553	<u>3/</u>
III ^{2/}						
IV	900	3.0	12,050	402	1,206	<u>3/</u>
V ^{2/}						
VI ^{2/}						
VII ^{2/}						
VIII ^{2/}						

As it happens, the table indicates no period in which the estimated number of trucks available was insufficient to carry the indicated load. If this had occurred, however, it would not necessarily have reflected an inconsistency in the figures because of the possibility of accumulating reserves. Assume for a moment that the number of trucks required to cover the daily deficit of 12,000 tons in Period IV, (major base), when the round trip haul was 900 km., had been greater than the number available; and assume further that in Period III there had been a rail surplus. Under these conditions it is highly probable that the German army

1/ It has been assumed that there were no rail hauls in this period, and that all supplies were carried by divisional and GHQ trucks.

2/ No figures are given for periods when it is believed there was no railway transport deficit, or only a negligible deficit.

3/ It has not been possible to estimate 30-ton trailers available, but it seems probable that they were greatly in excess of indicated need.

would have utilized the rail surplus available in Period III to bring up supplies to the major bases established in that period. Use of these reserves would so shorten the necessary average haul in Period IV that the inadequacy of trailers would disappear.

This technique of using excess capacity in a period of relatively low activity to accumulate reserves nearer the scene of operation, reducing the subsequent ton-mile load, and thus increasing flexibility, is fundamental to military supply. It is unfortunate, therefore, that time did not permit a more detailed analysis of the German supply problem on the Eastern Front, since this would undoubtedly have revealed wide fluctuation in supply expenditures within each of the eight broad periods for particular sectors of the front. In view of the transport facilities available, these fluctuations could only have been handled by accumulating reserves with a consequent bearing on the timing and scale of the tactics employed.

In closing this examination of rail capacity, some allusion should be made to the effects of military losses on the supply of motor vehicles and to those of weather on both motor and railway operation. In the calculations made above there was no allowance for a net reduction in the supply of vehicles during the campaign. In fact, it was implicitly assumed that the necessary replacements were available and were delivered. After the middle of the drive on Moscow, however, it is probable that average efficiency had been reduced (slower speeds, more breakdowns), even if the quantity of vehicles remained about the same,

and hence that more trucks would have been needed than is indicated in the table. The onset of winter weather would operate in the same direction; it may also have slowed train operation and increased the "deficit". Inability to continue the delivery of supplies for an indefinite period at the rate required by the unyielding Russian resistance may, therefore, have been the factor finally causing a halt in the German offensive.

G. Rolling Stock Requirements

In addition to the limitations placed on the power of the German offensive in Russia by the capacity of the captured railroad lines and the alternative means of transport, there is another factor capable of imposing limitations of supply on the German operations. This is the quantity of rolling stock available.

The factors which determine rolling stock requirements are principally four: tonnage hauled, capacity of individual cars, length of haul, and average distance moved by a car in a day.

1. Tonnage Hauled. The tonnages that had to be hauled for the German army in its Russian campaigns have already been estimated; and it has been shown that at times the capacity of the converted lines, and hence the quantity of supplies delivered by rail, was less than these requirements. In estimating the rolling stock requirements, therefore, we have used the smaller of the two figures, either the supplies used or the supplies delivered by rail.

On this basis, the daily average tonnage needed at or

hauled to the major bases during each of the eight periods, including service freight was:

Period	I	II	III	IV	V	VI	VII	VIII
Tonnage (thousands)	1/	125	125	125	104	92	98	112

2. Capacity of Cars. It has already been estimated that the average capacity of the cars used by the Germans on the Eastern Front was 16 tons. The number of cars needed to contain the materiel needed at or hauled to the major bases daily during the various periods therefore was:

Period	II	III	IV	V	VI	VII	VIII
Cars needed	7810	7810	7810	6500	5750	6125	7000

3. Length of Haul. The length of the haul from the initial supply bases to the major bases is also necessary to an estimate of rolling stock requirements. For the purposes of this study it was assumed that Warsaw^{2/} was the point of origin and the major bases the points of destination. The distances (in kilometers) between these points have been doubled to allow for the round trip, giving the following figures for length of average round-trip haul in each of the several periods:

Period	II	III	IV	V	VI	VII	VIII
Round-trip haul (km.)	750	900	1200	1500	1650	1800	1800

1/ It is assumed that there were no Russian rail lines available in the first period; it is therefore omitted from subsequent tables in this chapter.

2/ It will be recalled that Königsberg and Lublin were also postulated as initial supply bases. The distances from these cities to most points on the Eastern Front are roughly equal to those from Warsaw to the front, and the latter base alone has therefore been used for purposes of measuring length of haul.

4. Average Car Movement. It is now necessary only to know the average distance which cars move in a day in order to estimate the rolling stock requirements. On this point evidence has been assembled from a variety of sources.

The Transportation Corps of the AEF in 1918, for example, expressed the hope that the average achieved movement of freight cars would be 60 miles, or 100 kilometers, per day. This estimate which was made the basis for rolling stock requisitions by the Transportation Corps, caused some consternation in Washington, where, during the summer of 1918, it was felt in some quarters that the stated car speeds were too low and that the consequent demands for rolling stock were unreasonably high. The experience under operating conditions was no better, and may have been somewhat worse, than the estimates of the Transportation Corps.

The Railway Section of the Engineers' Corps at the present time makes estimates of car movements which are hardly different from those of the World War. After considerable study, it was felt there that present conditions would not materially alter the estimate of 100 kilometers per day for freight cars.

Car movements on the Southern Railway are in close accord with AEF experience. On this line, freight cars move from 44 to 62 miles per day, depending on seasonal and other variations.^{1/}

Further evidence is found in the Budd report of 1930. At this time the average daily movement of the Russian car was 108 kilometers, or about 65 miles. And finally, the average movement

^{1/} The range of American experience for all lines is more nearly like 20 to 125 miles a day.

of freight cars in Germany in 1938 was 60 miles a day. The AEF estimate is thus confirmed by evidence from a wide range of sources.

The figures cited may seem excessively low to the layman whose railroad experience is confined largely to fast passenger trains. But a vast number of invisible factors militate against the more rapid operation of freight cars which either do not arise in passenger-car operation or occur outside the experience of the average passenger. In the first place, the gross weight of freight trains is ordinarily greater than that of passenger trains, and lower speeds are therefore required. Loading and unloading are also much more time-consuming than is generally realized. Refueling and watering must also be included, as well as time necessary for the slow acceleration and deceleration of the heavily loaded freight trains.

The railwaymen consulted appeared, on the whole, to consider the figure of 60 miles a day rather too high than too low. Mr. Ernest Williams stated that he thought the Germans would do well to get 40 miles a day from their cars. When informed of the convergence of opinion in the neighborhood of 60 miles per day, he described this as a "good" average. He pointed out that the military would be particularly anxious to unload cars quickly at the front because of the vulnerability of large freight yards, as well as the desire to release the cars for further use.

The 60-mile figure has therefore been adopted for application to the German case. With this figure established, it is

possible to present a table indicating the number of **days** which were consumed by a car making the round trip from Warsaw to the major bases and return during the several periods:-

Period	II	III	IV	V	VI	VII	VIII
Days per round trip	7.5	9	12	15	16.5	18	18

The consideration of only a single additional figure is necessary before calculation of the rolling stock requirements is possible. This is the allowance that will have to be made for rolling stock lost to transport use for special reasons such as maintenance and repair, military damage, and use of cars for mobile storage. To take account of these factors the number of cars actually required to haul the tonnage indicated has been increased by 30 percent.

5. Car Requirements. Estimates of the German freight car requirements on the Eastern Front may therefore be calculated for each of the eight basic periods in the manner indicated in the table on the following page.1/

1/ Owing to the possibility of diverting locomotives from passenger to freight service, it has been assumed that no significant shortage would develop, and no consideration has been given to the problem.

TABLE 16. COMPUTATION OF ROLLING STOCK REQUIREMENTS

	(1) Daily supply require- ments (thou- sands of tons)	(2) Tons per car	(3) Days re- quired for one round trip	(4) Thousands of cars (1)+(2)x(3)	(5) 30% allow- ance (thou- sands of tons)	(6) Total cars re- quired (in thou- sands) (4)+(5)
II	125	16	7.5	58.5	17.5	76.0
III	125	16	9	70.2	21.1	91.3
IV	125	16	12	93.6	28.1	121.7
V	104	16	15	97.5	29.25	126.75
VI	92	16	16.5	94.9	28.5	123.4
VII	96	16	18	109.8	32.9	142.7
VIII	111	16	18	124.9	37.4	162.3

Note: 30% allowance is made in column 5 for cars in repair shops, destroyed, and used for mobile storage.

H. Rolling Stock Supply

It is impossible to avoid the conclusion that, compared with the rolling stock requirements encountered by the Germans on the Eastern Front, the supply at hand was more than sufficient to fulfill needs.

In 1938, Germany had some 600 thousand freight cars of all kinds. Since that time the amount of new production and the number of cars destroyed and otherwise lost to service cannot have been far from a balance.

But by military and political action Germany has acquired a greater or less measure of control over well-nigh the entire rolling stock of continental Europe. Inadequacies in the statistics and variation in type and capacity of cars make precision impossible, but it is likely that, all told, Germany has a fair measure of control over some 2 million freight cars. Many of these, however, have a smaller capacity, or are otherwise inferior to the German cars in this study. If appropriate adjustments are made for this factor, it is likely that the total freight car supply available to Germany was the equivalent of some 1,500,000 cars.

The highest figure reached in the estimate of cars needed for the supply of the Eastern Front was 163,000 or a bare 10 percent of the probable stock available. The question that arises is whether there was enough slack in the utilization of cars to permit this number to be readily released for military use, or whether the diversion interfered with economic activity and the military potential.

Consideration of the adequacy of the existing supply of rolling stock for present European needs lay outside the scope of this

study, and the evidence bearing on the question just posed is therefore scanty.

There is ample evidence of a general shortage of cars in Europe. Nevertheless, it is probable that sufficient slack existed to permit the necessary number of cars to be sent to Russia without impinging seriously on basic economic activity and the military potential. This slack probably existed chiefly at two points: the occupied countries and civilian passenger services generally. While cars had already been diverted in large numbers from service in the occupied countries to other uses, it is probable that, by completely disregarding the welfare of the people in these countries, a further number could be squeezed out. In this connection it may be noted that France, Belgium, and the Netherlands possessed alone, before the war, some 600,000 cars.

By repressing passenger service throughout Europe, further economies would be gained. Not only would the efficiency of freight operation be increased, but passenger cars might be used for freight service -- as, in fact, they have been, according to reports. Of the 200,000 European passenger cars, conversion to freight uses would apparently be possible for a large share, especially the third and fourth class cars, from which the partitions and benches could easily be removed. The load-capacity of converted cars would be relatively high. Compared to normal freight capacity of 10 to 25 tons, passenger cars of various sizes would have generally the same capacity. Four-wheel stock, for example, would carry 5 to 10 tons; six-wheel stock about 15 tons; and eight-wheel stock up to 20 tons. Cars of the first class, of which there are relatively

few, would probably have, after conversion, an average capacity in the neighborhood of 12 tons.

The doors on most such cars are only 3 feet wide, restricting their use for some purposes. They would be suitable for grain, merchandise, and the like, however, relieving an equivalent capacity of standard cars for military use.

Converted passenger cars, because of their superior brake equipment, could probably be operated more rapidly than the regular car. They all have air-brakes, while many European freight cars are still operated on hand brakes. Since the deceleration rate is a principal limiting factor on speed, an expedited service using the converted cars would be possible.

There is little likelihood that appreciable savings could be made through measures designed solely to increase the efficiency of the use of rolling stock. Although there are many reports of attempts to speed the loading and unloading of cars, to reduce the proportion of less-than-carload lots, to lengthen the average haul, and so on, it is believed that the opportunities for further improvement along these lines had been well exploited before the Russian campaign began. Even before outbreak of war in 1939 much had been accomplished along this line in Germany, and reports suggest that the necessary measures were tightened and extended as the war progressed and German territorial control widened. There is, however, no clear limit to the enlargement of operating economies, which can usually be pushed to undreamed lengths when the pressure becomes sufficiently great.

Similarly, there may have been undeveloped possibilities for the diversion of traffic to inland water-ways, while the reported steady increase in the use of producer-gas equipment in motor carriers widens still further the field of transportation facilities. On the latter point, however, it should be noted that before the war only 2 or 3 percent of total long-haul freight tonnage was carried by motor truck, and that since then many of the available vehicles have undoubtedly been taken over by the military.

In sum, it seems probable that the sacrifices imposed by the diversion of some 10 percent of the available rolling stock capacity of Europe to military use in Russia fall mainly on the civilian population, especially in the occupied countries. The productive effort, so far as it relates to the military potential, was probably affected little, if at all.

For the future, however, it is difficult to believe that additional rolling stock requirements-(above 165-175,000 cars) would not begin to affect basic economic activity. This is particularly important because, as the penetration of the German armies into Russia deepens, more cars will be required if Russian resistance, and hence the necessary weight of the German offensive, are maintained. The alternative would be to save cars by reducing the rate of delivery of supplies, thus curtailing the fighting power of the German armies.

An indication of the prospects confronting the High Command is given in the table on the following page. Taking the situation in the period of the final drive on Moscow as a beginning, the table shows, first, the increasing number of cars that

would be required to transport over successively greater distances the tonnages used in the period of the Moscow drive; second, it shows the decreasing tonnages that would be transported over these same distances if no more cars were used than the maximum number required in 1941. Briefly, the table indicates that for every 200 km. of further average advance along the whole front (involving an additional 400 km. round trip haul), the German army would require an additional 35,000 cars, or that, if the number of cars were held at the end-1941 level, the average tonnage that could be hauled each day would decline by about 10,000 tons for every further advance of 200 km.

TABLE 17. CAR REQUIREMENTS FOR OPERATIONS FROM
POSSIBLE FUTURE MAJOR BASES

Bases	Round ¹ / trip (km.)	Tonnage Carried ² / (Constant no. of cars)	Cars required ³ / (tonnage constant)
Smolensk	1,800	110	160
Rzhev	2,200	90	200
Kharkov	2,600	80	230
Taganrog	3,000	70	270
Yaroslavl	3,400	60	310
Kineshma	3,800	55	340
Kazan	4,200	50	380
Stalingrad	4,600	45	410
Astrakhan	5,000	40	450

¹/ Estimated round trip distance between each of the bases and Warsaw.

²/ Tonnage of supplies (in thousands) transportable daily by rail assuming use of only 160,000 freight cars, the number employed during final period of 1941 campaign, Nov. 18 - Dec. 6.

³/ Total car requirements (in thousands) assuming total supply requirements of 110,000 tons a day, the amount delivered by rail during the final phase of 1941 campaign.

I. The Problem of Supply in Winter

While the winter period, after December 6, 1941, does not fall strictly within the scope of this study, a concluding word on supply problems in winter may be in order.

Where the conditions with respect to temperature and snow are as severe as those in central and northern Russia, special problems arise. Locomotive frames, for example, are likely to crack. The Russians and Canadians have found that it was necessary to construct their locomotive frames of special alloy steels. Unless the Germans were using East European stock (which is thought to be adapted to winter operation) they may, therefore, have encountered difficulties for which they were not prepared. Similarly, their locomotives may not have been equipped with sanding mechanisms designed to prevent freezing up at very low temperatures. In that event, traction would be seriously reduced. Snow on the track would also be likely to cause slippage. Even more serious, perhaps, would be the difficulties due to drifting snow. While German engines were doubtless equipped with plows, which would keep the track clear from snow fall if traffic was fairly heavy, the drifting of snow into the railway cuts may have caused some difficulty. Consideration must also be given to the increased tractive effort required as a result of the congealing of lubricants, and to the loss of power through radiation. These factors, and the others mentioned, must not

be construed as having brought German railway operation in Russia to a halt. They have undoubtedly cut the capacity of the lines severely, largely through reducing the number of trains run per day, reducing the length of trains, and increasing the proportion of service freight.

The reduction in rail capacity in the winter was probably matched by a reduction in the quantities of supplies needed. In a special note to Chapter II some rough estimates are presented which suggest that the daily average consumption on the front during the winter was in the neighborhood of 30-35,000 tons. To this, however, must be added the special supplies required for the construction and heating of shelters, and to cover the exceptional combat losses of equipment probably suffered as a result of the weather. The resulting average figure for total requirements has not been computed, but it seems possible that, when compared with a recalculated figure of rail capacity during the winter, it might not permit accumulation of reserves at major bases and advance railheads in preparation for a spring drive. Should this be the case, the weight of any early pushes would be less than that of June 1941.

This situation is more likely to obtain on the Central and Northern Sectors than in the south. If this is the case German drives in these areas should not be expected at the earliest dates permitted by the weather, but a drive in the south, if strategically sound on other

grounds, may be expected close to April 6, the earliest date on which, according to the computation, mechanized operations become feasible.

The basis on which the dates mentioned above were calculated is presented in Chapter IV.

CHAPTER IV. CLIMATIC CONDITIONS ON THE RUSSIAN FRONT

The following are the earliest dates when climatic and ground conditions probably will be favorable for mechanized offensive operations along the present front (map, following p. ¹⁴⁷~~154~~).

Rostov Region: April 6th

Kharkov Region: April 15th

Moscow Region: April 24th

Leningrad Region: May 9th

Bases for these possibilities are: A. weather statistics for Kharkov compared with Warsaw, Poland; B. first mean daily temperatures of 32, 41, and 50 degrees Fahrenheit; C. precipitation amounts and distribution; D. drainage conditions.

A. Weather Statistice for Kharkov

Daily statistics for a period of 21 years were gathered for Kharkov from Russian sources. These were analyzed by the U. S. Soil Conservation Service and the results plotted to indicate probability of drought (Charts 1 and 2). Study of Chart 3 shows that the German advance into Poland was calculated to fall at the start of the fall period of high probability of a drought period 30 days long. By starting September 1, 1939, the German armies had increasingly greater probabilities of a dry weather period for the month of September. By the same reasoning, the Kharkov graphs show

that conditions in that region may be favorable any time after April 1 (approx.).

However, the thawing of the ground must be considered in this case.

B. Mean Daily Temperatures

Critical temperatures in this case are first mean daily temperatures of 32° F., the beginning of ground thawing, and 50° F. The latter indicates, to Russian agronomists, the approximate time after which there is no frost in the ground and the ground is ready for planting. The dates on which these temperatures occur at the specified places are given in Table 18 below.

TABLE 18. FIRST MEAN DAILY TEMPERATURE DATES 1/

Station	32° F.	41° F.	50° F.
Leningrad	Apr. 8	Apr. 29	May 21
Minsk	Mar. 24	Apr. 13	May 4
Moscow	Apr. 4	Apr. 21	May 8
Kiev	Mar. 16	Apr. 8	Apr. 27
Kharkov	Mar. 21	Apr. 9	Apr. 28
Rostov	Mar. 13	Apr. 1	Apr. 21
Odessa	Feb. 21	Mar. 22	Apr. 19

1/ From: Great Soviet Atlas, Vol. I.

Mechanized military movements could probably take place under favorable conditions about a week and a half prior to the date of the first mean daily temperature of 50° F. This is borne out by information from a U. S. Soil Conservation Service agent on soil conditions at Jefferson, (Strool), South Dakota, where the annual courses of temperature and precipitation correspond closely to those of Kharkov (Chart 4). In the vicinity of Jefferson the period of April 15 to 20 is the first when ground conditions permit continuous use of tractors and farm trucks.

The possibility of a German advance prior to the thawing period (various dates in March and April along the front) is recognized. However, the thawing period is about 25 or more days long at stations along the front and would probably be a very difficult time for mechanized military operations.

C. Monthly Precipitation

Monthly average amounts of precipitation are further proof that ground conditions are likely to be favorable at the dates of first mean daily temperatures of 50° F. along the front. None of the four stations along the front have more than two inches of rainfall during April or May, nor more than 10 per cent of the average annual rainfall during either of those months, as is indicated by Table 19 below.

TABLE 19. PRECIPITATION AMOUNTS FOR SELECTED STATIONS
IN EUROPEAN RUSSIA DURING MONTHS ADJACENT
TO SUGGESTED DATES 1/

Station	Feb.	Mar.	Apr.	May	June	Year
Leningrad			.9	1.6	1.9	18.5
Moscow			1.4	2.0	2.1	21.2
Kharkov		1.3	1.3	1.5	2.8	20.0
Rostov	1.6	1.2	1.5	1.6	2.4	17.9
Minsk			1.6	2.0	3.3	24.2
Kiev		1.4	1.7	1.6	2.3	20.8
Odessa	1.1	1.1	.9	1.1	2.1	14.5

1/ Koppen, W., Handbuch der Klimatologie, 2. Hälfte, Klimakunde von Russland in Europa und Asien, Berlin, 1939.

All stations have low annual precipitation although evaporation is much less in the vicinity of Leningrad than in Rostov. The thawing and drying period thus is slightly longer on the northern part of the front. The course of precipitation, as well as the curves of drought probability (Charts 1 and 2), show that if the campaign were postponed until the May 15-June 30 period, offensive operations would be commenced under less desirable conditions.

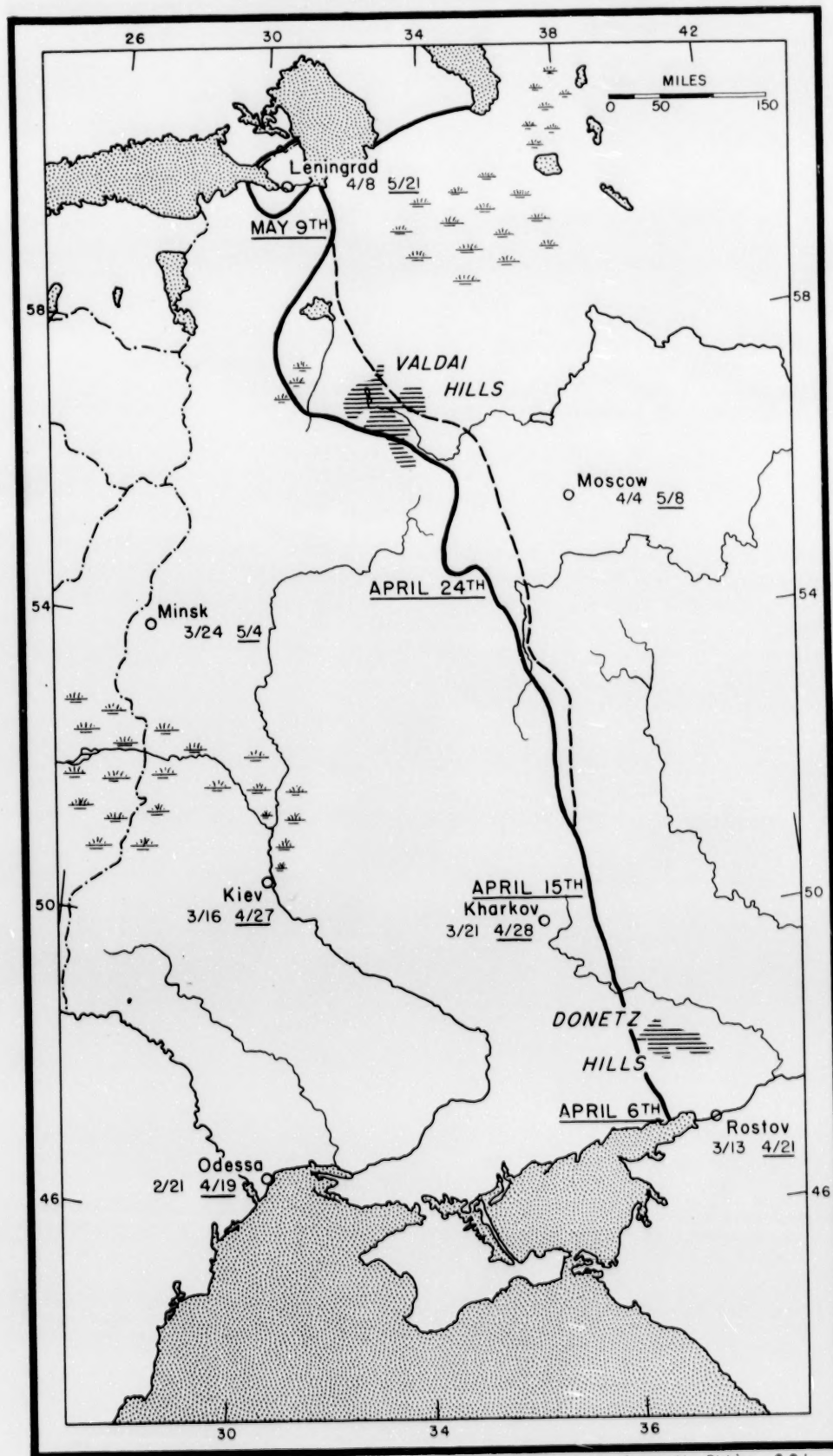
D. Drainage Conditions

Stream thawing along the front is from three weeks to a month prior to the suggested dates when conditions favor offensive action. Poor drainage in relatively large areas, therefore,

could slow up a German advance in only one possible sector on the suggested dates. At the present front between Leningrad and Moscow, the marshy area on the west side of the Valdai Hills extending north-south near the Lovat River might retard a German advance (see following map). Elsewhere, however, there would be only minor obstructions of this sort.

Map

THE RUSSIAN FRONT REGION



Map No. 311 Feb. 20, 1942

Compiled and Drawn in the Geographic Division, G.O.I.

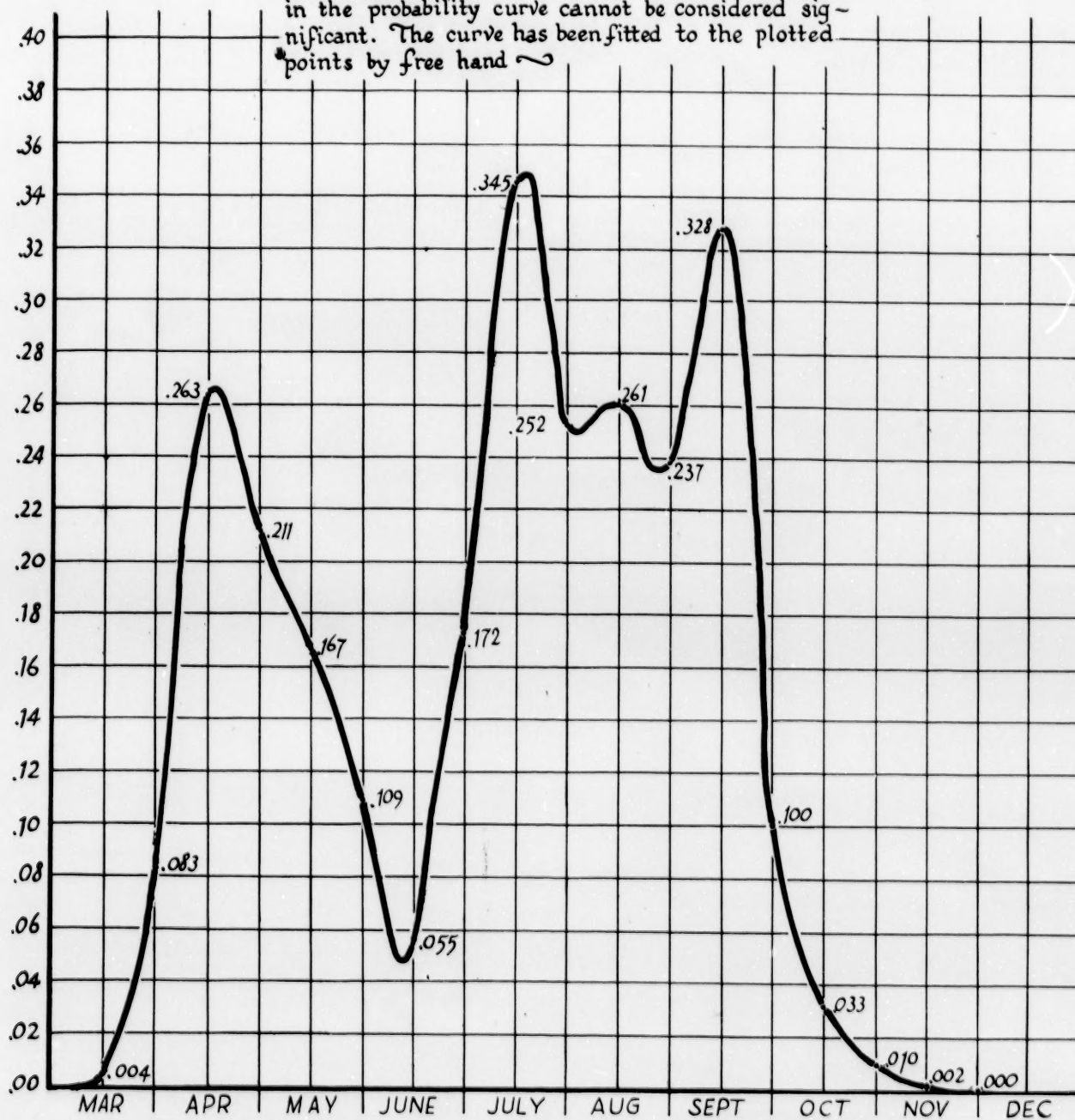
LEGEND

- 3/13 Date of First Mean Daily Temperatures of 32°F March 13
- 4/21 Date of First Mean Daily Temperatures of 50°F April 21
- APRIL 6TH** Date when German Offensive Might Start
- Russo-German Front Jan. 26, 1942
- Russo-German Front Dec. 31, 1941
- ▨ Elevations of 1000-2000 Feet
- ~ Swamp

Chart 1 Kharkov, USSR

Graph showing the probability of 30 days [subsequent to the date plotted on the axis of the abscissas] without the occurrence of either (1) rainfall in excess of 0.50 inch in any consecutive two days; or (2) observed snowfall in any amount.

N.B. The plotted probability figures are subject to large sampling error, and hence minor variations in the probability curve cannot be considered significant. The curve has been fitted to the plotted points by free hand.

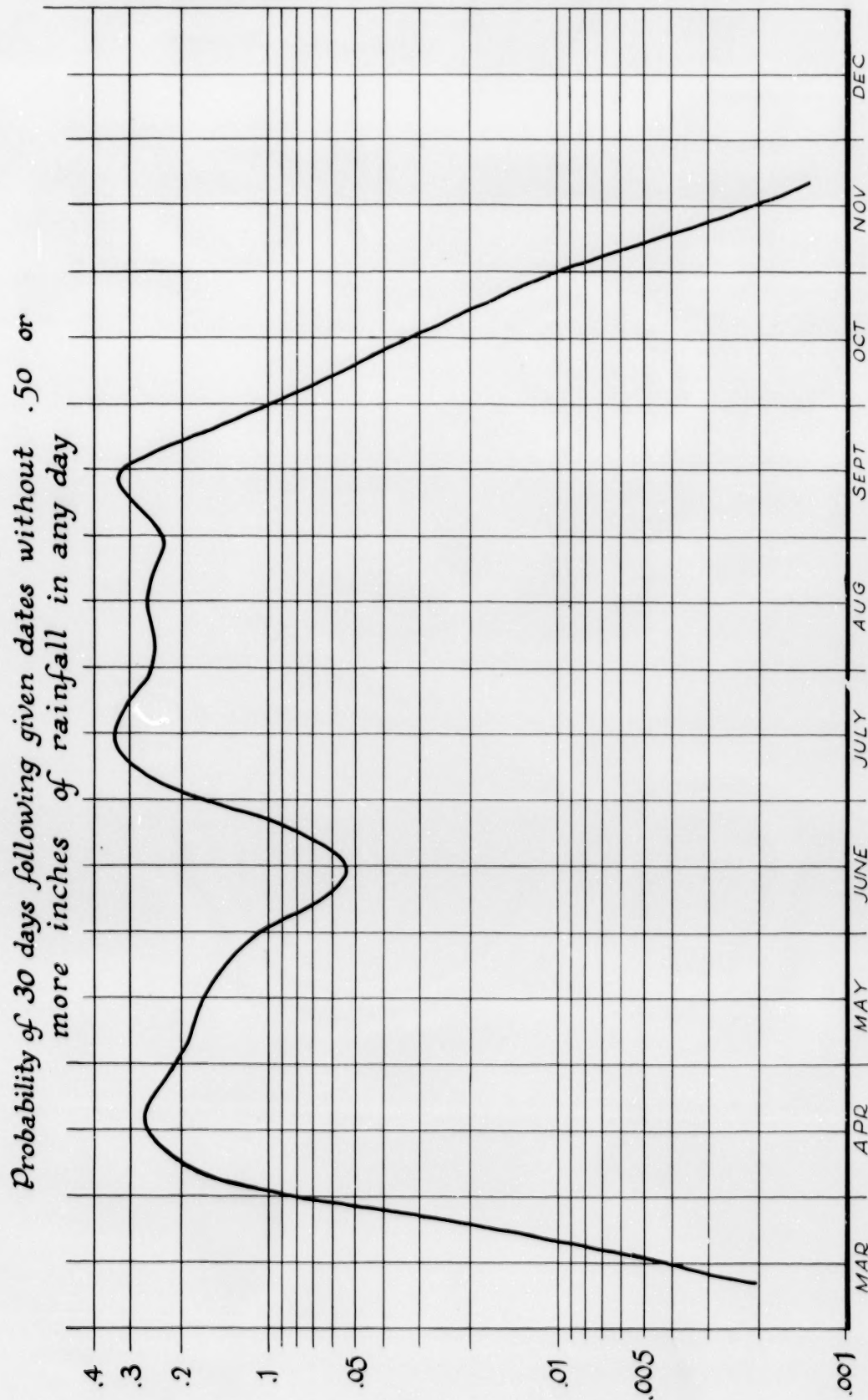


COMPILED BY THE DIVISION OF CLIMATIC AND PHYSIOGRAPHIC RESEARCH
SOIL CONSERVATION SERVICE

DRAWN IN THE CARTOGRAPHIC SECTION, GEOG. DIV., COI

Chart 11

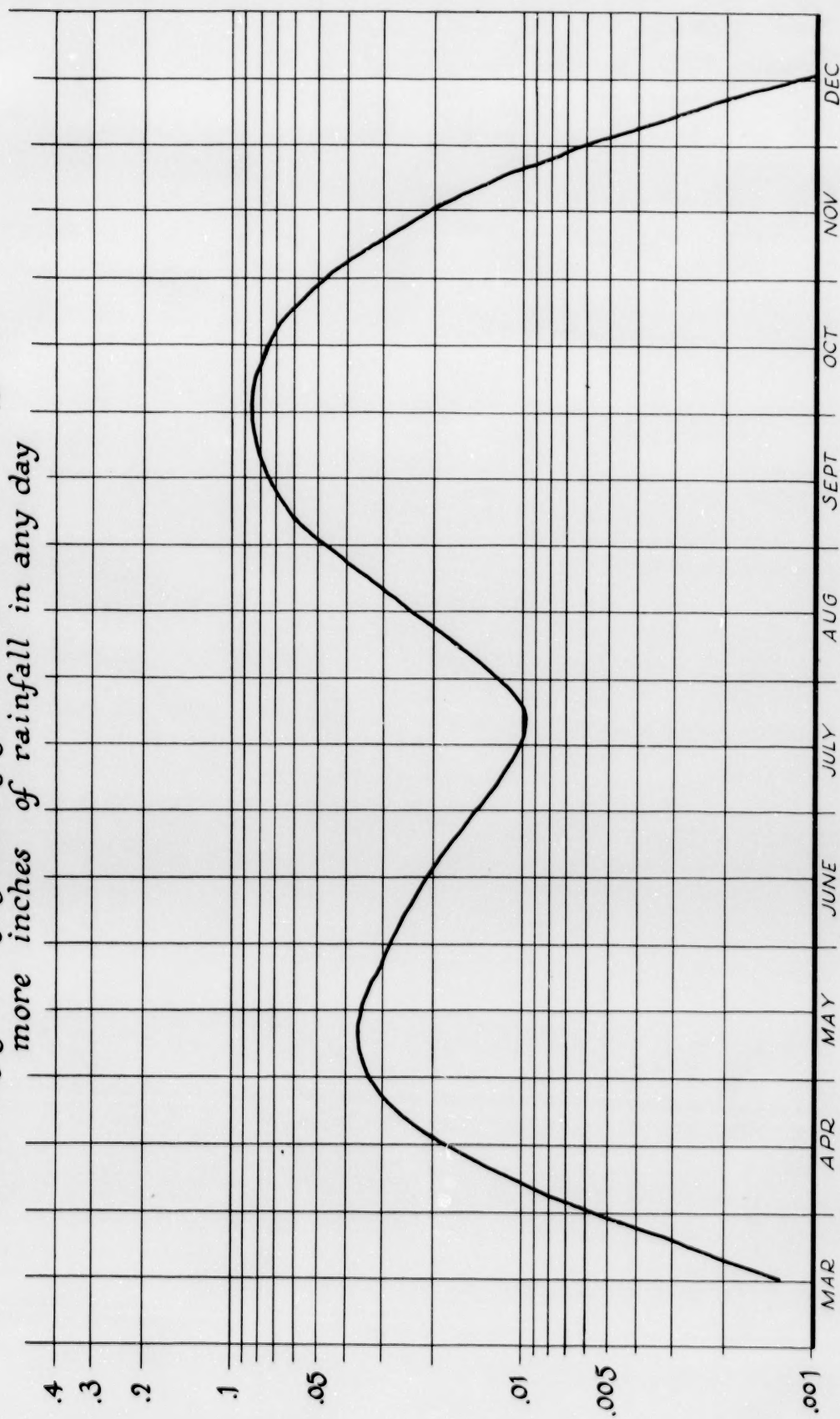
Kharkov, USSR



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DRAWN IN THE CARTOGRAPHIC SECTION, GEOG. DIV., COI

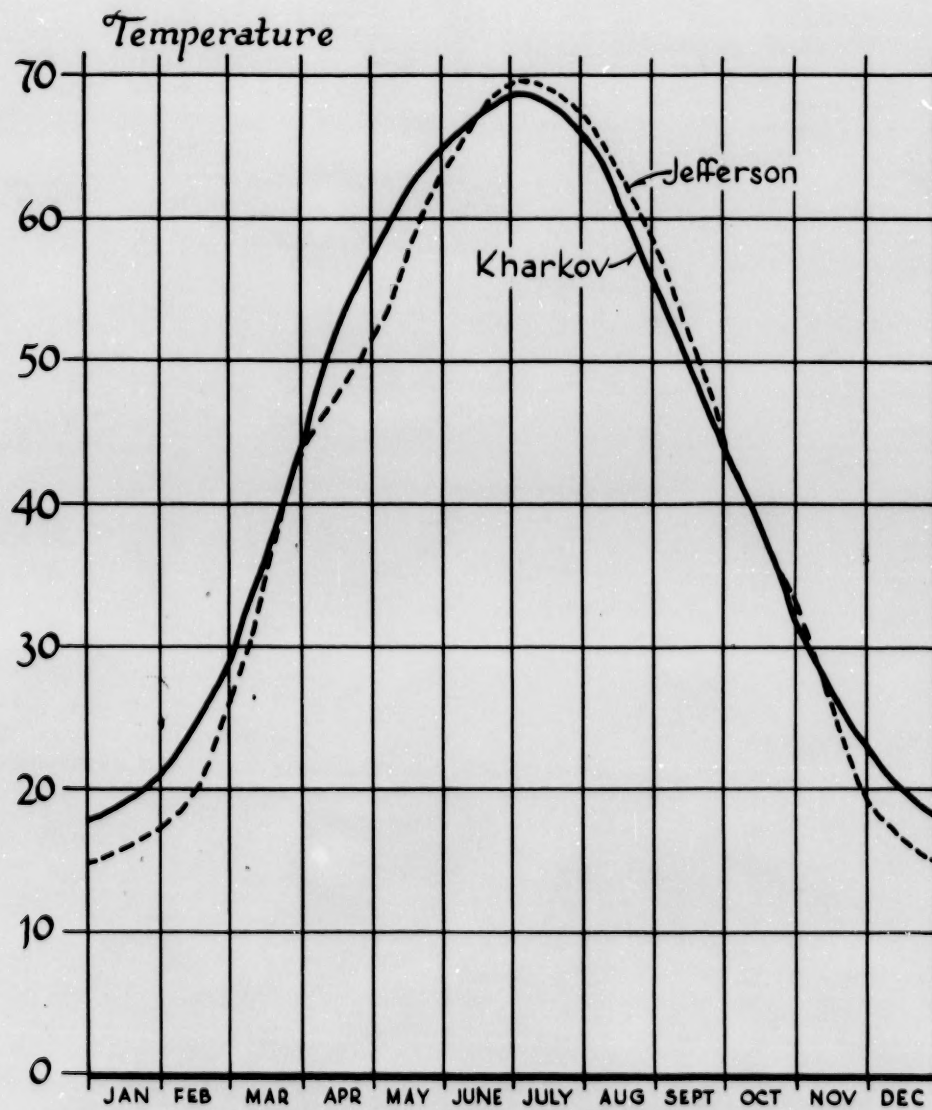
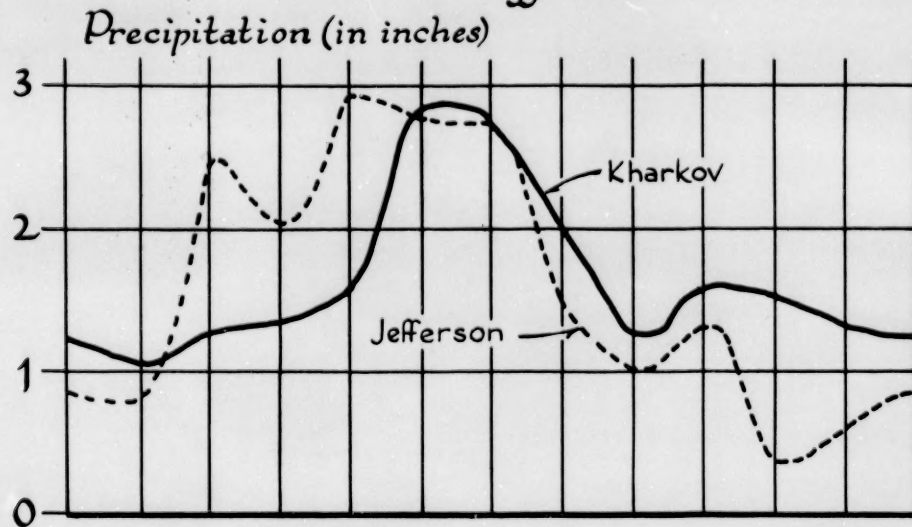
Chart III Warsaw, Poland

Probability of 30 days following given dates without .15 or more inches of rainfall in any day



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DRAWN IN THE CARTOGRAPHIC SECTION, GEOG. DIV., COI

Chart IV
Average Precipitation and Temperatures
of
Kharkov, U.S.S.R. & Jefferson (Strool) S.D.



COMPILED BY THE DIVISION OF CLIMATIC AND PHYSIOGRAPHIC RESEARCH
SOIL CONSERVATION SERVICE

GEOG. DIV., C.O.I.
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Fig. 5

APPENDIX TO CHAPTER I. GERMAN SUPPLY REQUIREMENTS ON THE
RUSSIAN FRONT DURING THE WINTER MONTHS

The estimated supply requirements of the German armies in Russia during winter operations (December 7 - March 1) involve two major assumptions: a withdrawal of substantial forces and a somewhat lower average rate of expenditure per active division. In view of the severity of weather conditions, plus the cumulative effects of 5½ months of campaigning and the necessity for refitting and conditioning, it seems reasonable to assume that the Germans withdrew practically all of their mechanized and motorized forces from the front. In addition, it is believed that a substantial number of infantry divisions were withdrawn. The total number of infantry divisions has been scaled down from the figure of 120 (December 6) to 80 (January 15).

While the action following December 6 has been characterized as Defensive Fighting, the ammunition expenditure during these winter periods was probably not so heavy as it was during the periods with the same designation in the summer and fall campaigns. The earlier defensive operations of the German forces were fitted into the pattern of a general offensive, which meant that forces committed to holding positions defensively could not indulge in the luxury of a retreat. There can be no doubt, furthermore, that winter conditions have pared down the scale of military operations on the Eastern Front, with the probable conse-

quence of cutting down the rate of supply expenditure per division as well.

Table 20 represents an attempt to make a rough estimate of the supply requirements of the German units stationed on the Russian front between December 7 and March 1. It is to be emphasized that in all its details it is highly conjectural, but it is based upon the broad assumptions already discussed, which are believed to be sound. The estimates suggest that over the entire period utilization of supplies average 32,642 tons per day, and total, on these rough assumptions, 2,269,842 tons.

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TABLE 20. ESTIMATE OF GERMAN SUPPLY REQUIREMENTS DURING THE WINTER
(DECEMBER 7 - MARCH 1)

	Dec. 7 - 15 (9 days)	Dec. 16 - Jan. 15 (31 days)	Jan. 16 - March 1 (44 days)
Total forces	120 Infantry 18 Panzer 22 Motorized	100 Infantry 12 Panzer 14 Motorized	80 Infantry 6 Motorized
Active forces	50 Infantry .4 <u>1</u> / 6 Motorized .2	40 Infantry .3 6 Motorized (15 days) .2	30 Infantry .3
Inactive forces	60 Infantry 18 Panzer 16 Motorized	60 Infantry 12 Panzer 6 Motorized (16 days) 8 Motorized	50 Infantry 6 Motorized
Tonnage Utilization	426,690	905,072	938,080
Average Tonnage Utili- zation per day (32,642)	47,410	29,196	21,320

1/ The decimal figures refer to the rate at which supplies were being expended in relation to a theoretical maximum rate of expenditure (1).

APPENDIX TO CHAPTER II

Note:

Tables 21-23 in this appendix give our estimates of the number of vehicles, guns, and other ordnance equipment in the basic units of the German army. Whenever it was possible to obtain the actual German figures, these were used. Otherwise data were adapted from the most comparable items used by the United States Army.

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TABLE 21a. GUNS - INFANTRY DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Pistol	5000	.001	.0011	5.5	0	4	0	.01
Rifle	11000	.005	.0055	61.	0	2	0	.041
Mach. Pist.	435	.0045	.0049	2.1	0	5	0	.003
Machine Gun								
Light	430	.0125	.0138	6	0	7	0	.02
Heavy	116	.027	.0292	3.1	0	7	0	.007
A. T. Gun								
20 mm. (also A.A.)	133	.5	.55	66.5	2	5	.04	1.12
37 mm.	75	.15	.165	12.4	0	4	0	.016
50 mm.	9	.3	.33	3	0	4	0	.004
7.9 Rifle	81	.01	.011	.9	0	5	0	.001
Mortar								
50 mm.	84	.015	.016	1.3	0	4	0	.002
81 mm.	57	.075	.0825	4.7	0	7	0	.011
75 mm.	20	.75	.825	16.5	0	3	0	.016
Howitzer								
105 mm.	36	3.	3.3	118.8	0	3	0	.119
150 mm.	14	1.5	1.65	23.4	0	3	0	.023
Heavy Guns								
75 mm.	20	1.5	1.65	33	0	3	0	.033
105 mm.	4	3	3.3	13.2	2	10	.009	.044
150 mm.	6	4	4.4	26.4	2	10	.0177	.088
TOTALS				397.8			.0667	1.558

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TABLE 21b. GUNS - MOTORIZED DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		replacement daily (tons)	
					Inactive	Active	Inactive	Active
Pistol	4500	.001	.0011	4.95	0	4	0	.007
Rifle	9000	.005	.0055	38.5	0	2	0	.026
Mach. Pist.	250	.0045	.0049	1.23	0	5	0	.002
Machine Gun								
Light	420	.0125	.0138	5.80	0	7	0	.015
Heavy	88	.027	.0292	2.57	0	7	0	.007
A.T. Gun								
20 mm. (also A.A.)	96	.5	.55	52.8	2	5	.035	.089
37 mm.	54	.15	.165	8.9	0	4	0	.012
50 mm.	9	.3	.33	3.0	0	4	0	.004
7.9 rifle	54	.01	.011	.6	0	5	0	.001
Mortar								
50 mm.	60	.015	.016	.96	0	4	0	.001
81 mm.	40	.075	.085	.34	0	7	0	.001
15 mm.	16	.75	.825	1.24	0	3	0	.001
Howitzer								
105 mm.	30	3	3.3	99.	0	3	0	.099
150 mm.	16	2.25	2.48	39.6	0	3	0	.039
Heavy Guns								
75 mm.	18	1.5	1.65	29.7	0	3	0	.030
105 mm.	4	3	3.3	13.2	2	10	.009	.044
150 mm.	5	4	4.4	22.0	2	10	.015	.073
TOTALS				324.39			.059	.451

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TABLE 21c. GUNS - PALMER DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Pistols	3500	.001	.0011	3.85	0	4	0	.005
Rifles	7000	.005	.0055	49.5	0	2	0	.033
Machine Pist. Machine Guns	400	.0045	.0049	1.96	0	5	0	.003
(Light) (Heavy)	1138	.02	.02	8.43	0	7	0	.022
A.T. Guns								
20 mm.	253	.5	.55	42.9	2	5	.029	.072
37 mm.	45	.15	.165	7.4	0	4	0	.010
Mortars								
50 mm.	3	.015	.016	.05	0	4	0	---
81 mm.	3	.075	.085	.25	0	7	0	.006
Howitzers								
105 mm.	24	3	3.3	79.2	0	3	0	.079
150 mm.	8	1.5	1.65	13.2	0	3	0	.013
Heavy Guns								
75 mm.	18	1.5	1.65	29.7	0	3	0	.030
105 mm.	4	3.	3.3	13.2	2	10	.009	.044
TOTALS				249.64			.038	.317

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TABLE 21d. GUNS - GHQ TROOPS (Per Infantry Division)

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Pistols	6630	.001	.0011	7	0	4	0	.009
Rifles	3380	.005	.0055	19	0	2	0	.013
Mach. Pist.	120	.0045	.0049	.6	0	5	0	.001
Machine Guns								
Light	206	.0125	.0138	2.8	0	7	0	.007
Heavy	186	.027	.0292	5	0	7	0	.012
A.T. Guns								
37 mm.	24	.15	.165	4	0	4	0	.005
75 mm.	22	1.5	1.65	36	0	4	0	.048
A.A. Guns								
Heavy machine	76	.027	.0292	2.2	2	7	.001	.005
37 mm.	136	.182	.2	27	0	2	0	.018
Howitzers								
155 mm.	32	1.5	1.65	53	0	3	0	.053
240 mm.	5	7.5	8.25	41	2	10	.027	.137
Heavy Guns								
155 mm.	16	4	4.4	70	2	10	.047	.233
Other Heavy	5	10	11	55	2	10	.037	.183
TOTALS				322.6			.112	.724

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TABLE 22a. VEHICLES - INFANTRY DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Trucks								
Light	237	2	2.2	522	4	8	.69	1.34
Medium	454	4	4.4	1996	4	8	2.65	5.31
Heavy	48	10	11	528	4	8	.7	1.40
Cars								
Medium	65	2	2.2	143	4	8	.19	.38
Heavy Armored	3	9	9.9	30	4	14	.04	.14
Motorcycles								
Solo	343	.28	.31	106	4	8	.14	.28
Side-car	150	.36	.40	59	4	8	.03	.16
Tractors & Half Tractors								
Medium	147	5	5.5	808	4	8	1.07	2.15
Heavy Armored	20	10	11	220	4	14	.29	1.027
Horse-Drawn Vehicles	819	.5	.55	451	4	8	.0	1.20
Other Vehicles								
Limbers - Motorized	75	.5	.55	41.2	0	2	0	.03
Limbers - Gun	48	.5	.55	26.4	0	2	0	.03
Caissons	96	.5	.55	52.7	0	2	0	.03
Trailers	2	.25	.27	.5	0	2	0	-
Bicycles	138	.025	.027	3.7	0	4	0	.005
Pontoon	20	.5	.55	11.0	0	4	0	.01
Pneu. Boats - Light	36	.175	.192	6.9	0	4	0	.009
Pneu. Boats - Heavy	40	.057	.062	.2	0	4	0	.009
Motor Boats	8	.5	.55	4.4	0	4	0	.005
TOTALS				5010.0			5.85	13.515

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TABLE 22b. VEHICLES - AUTHORIZED DIVISION

Item	No.	Wt. Per Unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement Percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Trucks								
Light	224	2	2.2	493	4	8	.656	1.311
Medium	1406	4	4.4	6186	4	8	8.227	16.455
Heavy	58	10	11.0	638	4	8	.848	1.700
Cars								
Medium	88	2	2.2	194	4	8	.258	.516
Heavy Armored	25	9	9.9	248	4	14	.330	1.158
Motorcycles								
Solo	1000	.28	.31	303	4	8	.410	.819
Sidecar	400	.36	.40	158	4	8	.210	.420
Tractors & Half Tractors								
Medium	420	5	5.5	2310	4	14	3.072	10.788
Heavy Armored	30	10	11.	330	4	14	.439	1.541
Other Vehicles								
Limbers and Caissons	220	.5	.55	121	0	2	0	.031
Trailers	2	.25	.28	.6	0	2	0	
TOTALS				10966.6			14.450	34.759

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TABLE 22c. VEHICLES - PANZER DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					Inactive	Active	Inactive	Active
Trucks	1,057	2	2.2	2322	4	8	3.083	6.176
Light	744	4	4.4	3273	4	8	4.353	8.706
Medium	105	10	11	1155	4	8	1.536	3.072
Heavy								
Cars	411	2	2.2	904	4	8	1.202	2.405
Medium	27	9	9.9	267	4	14	.355	1.245
Heavy Armored	50	6.5	7.15	353	4	14	.476	1.672
Light Armored	16	3	3.3	53	4	8	.070	.141
Heavy								
Motorcycles	650	.23	.308	200	4	8	.266	.532
Solo	350	.36	.396	139	4	8	.135	.370
Sidecar	318	5	5.5	1749	4	8	2.326	4.652
Tractors & Half Tractors								
Tanks	280	10	11	3080	4	14	4.096	14.383
Light	150	20	22	3300	4	14	4.389	15.411
Medium								
Other Vehicles	200	.5	.55	110	0	2	0	.073
Limbers & Caissons					0	4	0	.012
Pneu. Boats	36	.175	.192	6.92	0	4	0	.012
Light	40	.057	.062	2.48	0	4	0	.006
Heavy	8	.5	.55	4.4	0	4	0	.015
Motor Boats	20	.5	.55	11.0	0	4	0	
Pontoons								
TOTALS				1634.80			22.342	58.883

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TABLE 22d. ESTIMATED GHQ VEHICLES PER INFANTRY DIVISION

Item	No.	Wt. per unit (tons)	Plus 10% for parts	Total wt. (tons)	Replacement percentage (monthly)		Replacement daily (tons)	
					In-	Active	In-	Active
Trucks								
Light	370	2	2.2	814	4	8	1.083	2.165
Medium	1178	4	4.4	5183	4	8	6.893	13.787
Heavy	74	10	11	814	4	8	1.083	2.165
Cars								
Medium (incl. Ambu.)	44	2	2.2	97	4	8	.129	.258
Scout (with arm.)	46	4	4.4	202	4	8	.269	.537
Motorcycles								
Solo	118	.28	.308	36	4	8	.048	.096
Sidecar	112	.36	.396	44	4	8	.059	.117
Tractors								
Medium	10	5	5.5	55	4	8	.073	.146
Heavy	20	10	11	220	4	8	.293	.535
Other Vehicles								
Trailers	36	2	2.2	79	4	8	.105	.210
Mot. Tricycles	42	1	1.1	46	4	8	.061	.122
Misc.	50	2	2.2	110	4	8	.146	.293
TOTALS				7700			10.242	20.481

TABLE 23a. WEIGHT OF AMMUNITION - INFANTRY DIVISION

(per unit of fire)

Item	No. per Division	Rounds per U of F	Weight per U of F (tons)	Total weight per U of F (tons)
Pistol	5,000	7	.00021	1.050
Rifle	11,000	150	.0057	62.700
Machine Pistol	435	750	.0288	12.528
Machine Guns				
Light	430	3100	.1180	50.740
Heavy	116	900	.0337	3.909
A T Guns				
20 mm (Also AA)	133	900	.075	9.975
37 mm	75	100	.173	12.975
50 mm	9	50	.714	6.426
7.9 mm Rifle	81	150	.0057	.462
Mortars				
50 mm	84	100	.088	7.392
81 mm	57	100	.57	32.490
Howitzers				
75 mm	20	300	3.45	69.000
105 mm	36	225	5.62	202.320
150 mm	14	150	7.875	110.250
Heavy Guns				
75 mm	20	300	3.45	69.000
105 mm	4	75	4.	16.000
150 mm	6	100	7.0	42.000
Grenades	18,000	1	.0006	18.000
TOTAL				727.217

TABLE 23b. WEIGHT OF AMMUNITION - MOTORIZED DIVISION

(per unit of fire)				
Item	No. per Division	Rounds per U of F	Weight per U of F (tons)	Total weight per U of F (tons)
Pistol	4500	7	.00021	.945
Rifle	9000	150	.0057	51.300
Machine Pistol	250	750	.0288	7.200
Machine Guns				
Light	420	3100	.1180	49.560
Heavy	88	900	.0337	2.966
A T Guns				
20 mm (also AA)	96	900	.075	7.200
37 mm	54	100	.173	9.342
50 mm	9	150	.317	2.853
7.9 mm Rifle	54	150	.0057	.308
Mortars				
50 mm	60	100	.088	5.280
81 mm	40	100	.57	22.800
Howitzers				
75 mm	16	300	3.45	55.200
105 mm	30	225	5.62	168.600
150 mm	4 Inf.			
	12 Field	150	7.875	126.000
Heavy Guns				
75 mm	18	300	3.45	6.210
105 mm	4	75	4.	16.000
150 mm	5	100	7.	35.000
Grenades	10,000	1	.0006	6.000
TOTAL				572.764

TABLE 23c. WEIGHT OF AMMUNITION-PANZER DIVISION

(per unit of fire)

Item	No. per Division	Rounds per U of F	Weight per U of F (tons)	Total Weight Per U of F (tons)
Pistol	3500	7	.00021	.735
Rifle	7000	150	.0057	39.900
Machine Pistol	400	500	.0191	7.640
Machine Guns				
Light	383	4000	.15	57.450
Heavy	78	900	.075	5.850
Guns in Tanks				
Light Mach. Gun	755	3000	.118	89.090
Heavy Mach. Gun	175	3000	.25	43.750
37 mm	80	90	.08	6.400
75 mm	75	90	.45	33.750
A T Gun				
37 mm	45	100	.173	7.785
Mortars				
50 mm	3	100	.088	.264
81 mm	3	100	.57	1.710
Howitzers				
105 mm	24	225	5.62	134.880
150 mm	8	150	7.87	62.960
Heavy Guns				
75 mm	18	300	3.45	62.100
105 mm	4	75	4.	16.000
Grenades	6000	1	.0006	3.600
TOTAL				573.864

TABLE 23d. WEIGHT OF AM UNITION - G H Q TROOPS
(per unit of fire)

Item	No. per Division	Rounds per U of F	Weight per U of F (tons)	Total Weight per U of F (tons)
Pistol	6630	7	.00021	1.392
Rifle	3380	150	.0057	19.266
Machine Pistol	120	750	.0288	3.456
Light	206	3100	.1180	24.308
Heavy	186	900	.0337	6.268
AA Guns				
Heavy Machine	76	5000	.1960	14.896
37 mm	136	300	.54	.734
A T Guns				
37 mm	24	100	.173	4.152
75 mm	22	40	.472	10.384
Howitzers				
155 mm	32	150	7.875	252.000
240 mm	5	50	10.	50.000
Heavy Guns				
155 mm	16	100	7.0	112.000
Other Guns	5	50	25.	125.000
TOTAL				623.856

APPENDIX TO CHAPTER III

The principal physical and operational factors affecting the tonnage capacity of railroads may be topically summarized in the manner given below. The topical arrangement is by static factors, while the dynamic, or variable, factors which they chiefly influence are indicated in parentheses.

Principal Factors Affecting the Capacity of Railroads

- (1) Number of tracks; frequency and length of passing tracks (speed and spacing of trains).
- (2) Grades (size of locomotives and/or weight of trains).
- (3) Curves (speed of trains).
- (4) Signal system (speed and spacing of trains).
- (5) Ballast, fills, ties, weight of rail, anchoring of rail against lengthwise movement, or "creep," bridges (speed and weight of trains; size of locomotives; maintenance, and hence proportion of service freight).
- (6) Water and fuel supply, quality, and stations (proportion of service freight to pay load).

Terminal Facilities

- (1) Size of yards, amount of trackage (speed of loading and unloading of cars; movement of cars; likelihood of delays through unexpected overcrowding).
- (2) Platforms and mechanical equipment (speed of

loading and unloading cars; movement of cars).

Motive Power and Rolling Stock

- (1) Locomotives, tractive power (speed and size of trains).
- (2) Locomotives, ratio of switching and yard to road engines (loading and unloading of cars).
- (3) Freight cars, capacity (tractive effort required per ton of net load; small cars required relatively more tractive effort).
- (4) Freight cars, braking power (speed and size of trains).
- (5) Freight cars, construction (speed and size of trains; ratio of net to gross weight).
- (6) Freight cars, draft gear (size and speed of trains).

Maintenance and Repair Facilities

- (1) For the permanent way (q.v.).
- (2) For terminal facilities (q.v.).
- (3) For motive power and rolling stock (q.v.).

Personnel

- (1) Efficiency of train crews (speed and spacing of trains; delays).
- (2) Efficiency of train dispatchers (speed and spacing of trains; delays).
- (3) Efficiency of general administration (all factors).

(4) Skill in loading and unloading (speed and size of trains; movement of cars).

(5) Speed in loading and unloading (movement of cars).

This is not an exhaustive list. It omits especially such large uncontrollable factors as the character and balance of traffic, which affects the average length of haul, and also the arrangement of types of trains according to a more or less efficient pattern; and the weather, which affects the speed, spacing, and weight of trains, the loading, unloading, and idle time of cars, and locomotives, the frequency and length of unexpected delays, and the like.